IMAGE DISPLAY

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TECHNICAL FIELD

[0001] The present invention relates to image display apparatus and, more particularly, to a head- or face-mounted image display apparatus that can be retained on the observer's head or face.

BACKGROUND ART

[0002] Image display apparatus designed to observe an image of a single image display device with two eyes have heretofore been known in Japanese Patent Application Unexamined Publication Number (hereinafter referred to as "JP(A)") 5-176260, 9-61748, 9-181998 and 9-181999.

[0003] An illuminating method for an image display apparatus designed to observe an image of a single image display device with two eyes has been known, for example, in JP(A) 7-318851.

[0004] Among them, the image display apparatus of JP(A) 5-176260 splits and folds light rays by a prism in the shape of an isosceles triangular prism and a mirror. Therefore, various aberrations are corrected by a lens placed in front of the pupil. This makes it difficult to correct aberrations, and at the same time, causes the apparatus to become large in size. In JP(A) 9-61748, display light from an LCD (liquid crystal display device) is split by using a half-mirror so as to be observed with two eyes. Because the display light is distributed to the left and right eyeballs, the image for observation becomes weak and dark. In JP(A) 9-181998 and 9-181999, because prisms are integrated, the prism structure is very large in size and requires a great deal of time and cost when it is produced by injection molding. In addition, correction of decentration aberrations is insufficient.

[0005] Regarding an illuminating method for use in a case where a display image from a single display device is observed with two eyes, when an arrangement such as that disclosed in JP(A) 7-318851 is adopted, because images led to the left and right eyes are in reversed relation to each other, the display image needs to be electrically switched for the left and right by the display device or other device.

DISCLOSURE OF THE INVENTION

[0006] The present invention was made in view of the above-described problems with the prior art, and an object of the present invention is to provide an image display apparatus, e.g. a head-mounted image display apparatus, in which an image from a single image display device is led to two eyes without using a half-mirror, thereby allowing observation of a bright image, and in which a power is given to an optical path distributing means placed at the middle between the two eyes to facilitate the correction of various aberrations. In addition, an object of the present invention is to provide an illuminating method which is the most suitable for observation of a single panel (single image display device) with two eyes, and which can be used without the need to switch the display image for the left and right.

[0007] An image display apparatus according to the present invention provided to attain the above-described object has an image display device for displaying an image to be observed by an observer, an optical path distributing mirror for distributing the image to an optical path for a right eye and an optical path for a left eye, an ocular prism for the right eye that is placed on the right-hand side of the optical path distributing mirror, and an ocular prism for the left eye that is placed on the left-hand side of the optical path distributing mirror.

[0008] The optical path distributing mirror has a mirror surface placed to face the image display device to reflect a display light beam emanating from the image display device so as to distribute the display light beam to the ocular prism for the right eye and the prism for the left eye. The mirror surface has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

[0009] The ocular prism for the right eye has a first surface through which the light beam of the optical path for the right eye reflected by the optical path distributing mirror enters the prism, a second surface which reflects the light beam of the optical path for the right eye within the prism, and a third surface through which the light beam of the optical path for the right eye exits from the prism.

[0010] The ocular prism for the left eye has a first surface through which the light beam of the optical path for the left eye reflected by the optical path distributing mirror enters the prism, a second surface which reflects the light beam of the optical path for the left eye within the prism, and a third surface through which the light beam of the optical path for the left eye exits from the prism.

[0011] At least the second surface of the ocular prism for the right eye, which is a reflecting surface, and the second surface of the ocular prism for the left eye, which is a reflecting surface, have a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

[0012] Another image display apparatus according to the present invention has an image display device for displaying an image to be observed by an observer, an optical path distributing prism for distributing the image to an optical path for a right eye and an optical path for a left eye, an ocular prism for the right eye that is placed on the right-hand side of the optical path distributing prism, and an ocular prism for the left eye that is placed on the left-hand side of the optical path distributing prism.

[0013] The optical path distributing prism has at least a first surface placed to face the image display device so that a display light beam emanating from the image display device enters the prism through the first surface, a second-first surface which reflects the optical path for the right eye entering through the first surface, a second-second surface which reflects the optical path for the left eye entering through the first surface, a third-first surface through which the light beam of the optical path for the right eye exits from the prism, and a third-second surface through which the light beam of the optical path for the left eye exits from the prism.

[0014] To form a relay image for the right eye from the image displayed by the image display device in the optical path for the right eye and to form a relay image for the left eye from the image displayed by the image display device in the optical path for the left eye, the optical path distributing prism is arranged so that at least the second-first surface and the second-second surface have a curved surface configuration that gives a power to the light beam, and the second-first surface and the second-second surface have the same surface configuration.

[0015] The ocular prism for the right eye has a first surface through which the light beam of the optical path for the right eye exiting from the third-first surface of the optical path distributing prism enters the prism, a second surface which reflects the light beam of the optical path for the right eye within the prism, and a third surface through which the light beam of the optical path for the right eye exits from the prism.

[0016] The ocular prism for the left eye has a first surface through which the light beam of the optical path for the left eye exiting from the third-second surface of the optical path distributing prism enters the prism, a second surface which reflects the light beam of the optical path for the left eye within the prism, and a third surface through which the light beam of the optical path for the left eye exits from the prism.

[0017] At least the second surface of the ocular prism for the right eye, which is a reflecting surface, and the second surface of the ocular prism for the left eye, which is a reflecting surface, have a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

[0018] With the above-described arrangement, the present invention can provide an image display apparatus, e.g. a head-mounted image display apparatus, in which an image from a single image display device is led to two eyes without using a half-mirror, thereby allowing observation of a bright image, and the correction of various aberrations is facilitated by placing an optical path distributing mirror or an optical path distributing prism at the middle between the two eyes. Further, it is possible to obtain an illuminating arrangement which is the most suitable for observation of a single panel with two eyes, and which can be used in the above-described arrangement without the need to switch the display image for the left and right.

[0019] Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification.

[0020] The invention accordingly comprises the features of construction, combinations of elements, and arrangement of parts which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a ray path diagram of an image display apparatus according to Example 1 of the present invention. Fig. 2 is a ray path diagram of an image display apparatus according to Example 2 of the present invention. Fig. 3 is a ray path diagram of an image display apparatus according to Example 3 of the present invention. Fig. 4 is a ray path diagram of an image display apparatus according to Example 4 of the present invention. Fig. 5 is a ray path diagram of an image display apparatus according to Example 5 of the present invention. Fig. 6 is a ray path diagram of an image display apparatus according to Example 6 of the present invention. Fig. 7 is a ray path diagram of an image display apparatus according to Example 7 of the present invention. Fig. 8 is a ray path diagram of an image display apparatus according to Example 8 of the present invention. Fig. 9 is a ray path diagram of an image display apparatus according to Example 9 of the present invention. Fig. 10 is a ray path diagram of an image display apparatus according to Example 10 of the present invention. Fig. 11 is a ray path diagram of an image display apparatus according to Example 11 of the present invention. Fig. 12 is a ray path diagram of an image display apparatus according to Example 12 of the present invention. Fig. 13 is a ray path diagram of an image display apparatus according to Example 13 of the present invention. Fig. 14 is a ray path diagram of an image display apparatus according to Example 14 of the present invention. Fig. 15 is a ray path diagram of an image display apparatus according to Example 15 of the present invention. Fig. 16 is a diagram for describing an image display apparatus according to Example 16 of the present invention. Fig. 17 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 17 of the present invention. Fig. 18 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 18 of the present invention. Fig. 19 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 19 of the present invention. Fig. 20 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 20 of the present invention. Fig. 21 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 21 of the present invention. Fig. 22 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 22 of the present invention. Fig. 23 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 23 of the present invention. Fig. 24 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 24 of the present invention. Fig. 25 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 25 of the present invention. Fig. 26 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 26 of the present invention. Fig. 27 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 27 of the present invention. Fig. 28 is a horizontal sectional view showing optical systems for two eyes of an image display apparatus according to Example 28 of the present invention. Fig. 29 is a ray path diagram of image display apparatus according to Examples 29 and 30 of the present invention. Fig. 30 is a diagram for describing the definition of parameters alpha and beta . Fig. 31 is a diagram for describing the definition of parameters L and D. Fig. 32 is a horizontal sectional view of an optical system for a right eye according to Example 29. Fig. 33 is a horizontal sectional view of an optical system for a right eye according to Example 30. Fig. 34 is an aberrational diagram showing lateral aberrations in the optical system of Example 16. Fig. 35 is an aberrational diagram showing lateral aberrations in the optical system of Example 20. Fig. 36 is an aberrational diagram showing lateral aberrations in the optical system of Example 22. Fig. 37 is an aberrational diagram showing lateral aberrations in the optical system of Example 29. Fig. 38 is an aberrational diagram showing lateral aberrations in the optical system of Example 30. Fig. 39 is a diagram for describing an arrangement of the image display apparatus according to the present invention when arranged to allow see-through observation. Fig. 40 is a perspective view illustrating the structure of an organic EL image display device. Fig. 41 is a view showing the way in which the image display apparatus according to the present invention is fitted on an observer's head.

BEST MODE OF CARRYING OUT THE INVENTION

[0022] The image display apparatus according to the present invention will be described below by way of examples. Figs. 1 to 15 are ray path diagrams respectively showing image display apparatus according to Examples 1 to 16 of the present invention.

[0023] In Example 1 shown in Fig. 1, a right eye of an observer is denoted by ER, and a left eye of the observer is denoted by EL. An image display device of an image display apparatus is denoted by reference numeral 3. An exit pupil for the right eye is denoted by 4R, and an exit pupil for the left eye is denoted by 4L. A decentered prism member placed in front of the right eye as an optical system for the right eye is denoted by 2R, and a decentered prism member placed in front of the left eye as an optical system for the left eye is denoted by 2L. In addition, an optical path distributing mirror placed at the middle between the

two eyes is denoted by 1. The decentered prism members 2R and 2L are made of a transparent medium having a refractive index larger than 1. In the following description, surfaces stated to be reflecting surfaces are mirror surfaces formed by providing mirror coatings on the relevant surfaces of the decentered prism members except totally reflecting surfaces.

[0024] Example 1 is arranged as shown in Fig. 1, which shows a horizontal section (YZ-section) thereof. The optical path distributing mirror 1 at the middle between the two eyes has a reflecting surface 1R for a right optical path and a reflecting surface 1L for a left optical path, which have symmetric configurations with respect to a plane of symmetry between the two eyes (i.e. a plane passing through the center of a line segment connecting the respective centers of the exit pupil 4R for the right eye and the exit pupil 4L for the left eye at right angles to the line segment).

[0025] The decentered prism member 2R, which constitutes an optical system for the right eye, and the decentered prism member 2L, which constitutes an optical system for the left eye, have the same configuration and are placed in symmetry with respect to the plane of symmetry between the two eyes. The decentered prism member 2R and the decentered prism member 2L each have, in order in which rays pass, a first surface 21R (21L), a second surface 22R (22L), a third surface 23R (23L), and a fourth surface 24R (24L). The second surface 22R (22L) and the fourth surface 24R (24L) are the identical surface. The identical surface serves as both a totally reflecting surface and a transmitting surface.

[0026] The image display device 3 is placed to face the optical path distributing mirror 1 on the observer side of the latter. The exit pupils 4R and 4L are located approximately in the same plane, facing the fourth surfaces 24R and 24L of the decentered prism members 2R and 2L, respectively. The surfaces 21R to 24R, 21L to 24L, 1R and 1L of the decentered prism members 2R and 2L and the optical path distributing mirror 1 are formed from free-form surfaces expressed by equation (a), which will be described later. Each of the free-form surfaces can be replaced with a spherical surface including a plane surface, an aspherical surface, an anamorphic surface, or an anamorphic aspherical surface.

[0027] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the reflecting surface 1R of the optical path distributing mirror 1 and reflected by the reflecting surface 1R so as to enter the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism and is incident on the second surface 22R at an incident angle not less than the critical angle, thereby being totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. It should be noted that no intermediate image is formed in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0028] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing three reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In addition, because one surface of the optical path distributing mirror 1 is used to distribute display light to the left and right optical paths, the production is easier than in the case of a prism having a multiplicity of surfaces, and the weight of the display apparatus can be reduced, advantageously. Furthermore, because the image display device 3 is located on the observer side, the whole display apparatus does not project forward to a considerable extent. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JP(A) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 1R and 1L of the optical path distributing mirror 1, it becomes possible to correct decentration aberrations very favorably.

[0029] Further, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the optical path distributing mirror 1 at the middle between the two eyes.

[0030] Fig. 2 shows a horizontal section (YZ-section) of Example 2. Example 2 has a common negative lens 5 inserted in the optical path from the image display device 3 to the reflecting surface 1R for the right optical path and the reflecting surface 1L for the left optical path of the optical path distributing mirror 1 in the arrangement of Example 1. The arrangement of the rest of Example 2 and the optical paths therein are the same as in Example 1. No intermediate image is formed as in the case of Example 1. A diffractive optical element or a lenticular lens may be used in place of or in addition to the negative lens 5. By inserting the negative lens 5 or the like between the image display device 3 and the optical path distributing mirror 1, aberrations can be corrected even more favorably. The use of a diffractive optical element or a lenticular lens allows the left and right optical paths to be divided from each other even more easily.

[0031] Fig. 3 shows a horizontal section (YZ-section) of Example 3. Example 3 uses an optical path distributing prism 10 formed from a decentered prism member with five surfaces in place of the optical path distributing mirror 1 placed at the middle between the two eyes in Examples 1 and 2. The decentered prism members 2L and 2R for the left and right eyes are the same as those in Examples 1 and 2.

[0032] The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes. The optical path distributing prism 10 has five surfaces: a first surface 11 as a transmitting surface located on the observer side of the image display device 3; a second surface 12R as a reflecting surface for the right optical path and a second surface 12L as a reflecting surface for the left optical path, which are located at both sides of the first surface 11 on the observer side thereof; and a transmitting surface 13L for the left optical path and a transmitting surface 13R for the right optical path, which are located on the observer sides of the second surfaces 12R and 12L. The first surface 11 has a symmetric configuration with respect to the plane of symmetry between the two eyes. The second surfaces 12R and 12L have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The third surfaces 13L and 13R have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the side of the optical path distributing prism 10 remote from the observer.

[0033] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The incident light is incident on the second surface 12R as a reflecting surface for the right optical path and reflected by the second surface 12R. The reflected light passes through the transmitting surface 13R for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R at an incident angle not less than the critical angle and thus totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0034] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing three reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In a case where no intermediate image is formed, it is difficult to ensure the required back focus, and a wide field angle cannot be obtained. In the case of this example, however, because an intermediate image is formed once, it is possible to correct aberrations favorably even at a wide field angle. In addition, because the exit surfaces and reflecting surfaces of the optical path distributing prism 10 are not surfaces shared between them, decentration aberrations can be corrected favorably. Because the reflecting surfaces 12R and 12L of the optical path distributing prism 10 do not use total reflection, it is possible to reduce the angle of incidence on the surfaces and to relax the requirement for the surface manufacturing accuracy. Furthermore, because the image display device 3 is located away from the observer, it does not interfere with the observer's nose. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JP(A) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 12R and 12L of the optical path distributing prism 10, it becomes possible to correct decentration aberrations very favorably.

[0035] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be made compact. Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0036] Fig. 4 shows a horizontal section (YZ-section) of Example 4. Example 4 uses an optical path distributing prism 10 formed from a decentered prism member with five surfaces in place of the optical path distributing mirror 1 placed at the middle between the two eyes in Examples 1 and 2. The decentered prism members 2L and 2R for the left and right eyes are the same as those in Examples 1 and 2. A major difference from Example 3 is in the placement of the image display device 3. In Example 4, the image display device 3 is disposed on the observer side of the optical path distributing prism 10.

[0037] The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes. The optical path distributing prism 10 has five surfaces: a first surface 11 as a transmitting surface located on the side of the image display device 3 remote from the observer; a third surface 13R as a transmitting surface for the right optical path and a third surface 13L as a transmitting surface for the left optical path, which are located at both sides of the first surface 11 on the side thereof remote from the observer; and a second surface 12L as a reflecting surface for the left optical path and a second surface 12R as a reflecting surface for the right optical path, which are located on respective sides of the third surfaces 13R and 13L remote from the observer. The first surface 11 has a symmetric configuration with respect to the plane of symmetry between the two eyes. The third surfaces 13R and 13L and the second surfaces 12L and 12R have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the observer side of the optical path distributing prism 10.

[0038] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The incident light is incident on the second surface 12R as a reflecting surface for the right optical path and reflected by the second surface 12R. The reflected light passes through the transmitting surface 13R for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R at an incident angle not less than the critical angle and thus totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0039] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing three reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In a case where no intermediate image is formed, it is difficult to ensure the required back focus, and a wide field angle cannot be obtained. In the case of this example, however, because an intermediate image is formed once, it is possible to correct aberrations favorably even at a wide field angle. In addition, because the exit surfaces

and reflecting surfaces of the optical path distributing prism 10 are not surfaces shared between them, decentration aberrations can be corrected favorably. Because the reflecting surfaces 12R and 12L of the optical path distributing prism 10 do not use total reflection, it is possible to reduce the angle of incidence on the surfaces and to relax the requirement for the surface manufacturing accuracy. Furthermore, because the image display device 3 is located on the observer side, the whole display apparatus does not project forward to a considerable extent. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JP(A) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 12R and 12L of the optical path distributing prism 10, it becomes possible to correct decentration aberrations very favorably.

[0040] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be made compact. Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0041] Fig. 5 shows a horizontal section (YZ-section) of Example 5. Example 5 uses an optical path distributing prism 10 formed from a decentered prism member with three surfaces in place of the optical path distributing prism 10 formed from a decentered prism member with five surfaces in Examples 3 and 4. The decentered prism members 2L and 2R for the left and right eyes are the same as those in Examples 1 to 4.

[0042] The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes. The optical path distributing prism 10 has three surfaces: a first surface 11 as a transmitting surface located on the observer side of the image display device 3; a second surface 12R as a reflecting surface for the right optical path and a second surface 12L as a reflecting surface for the left optical path, which are located at both sides of the first surface 11 on the observer side thereof and function as totally reflecting surfaces; a transmitting surface 13L for the left optical path, which is the identical with the second surface 12R as a reflecting surface for the right optical path; and a transmitting surface 13R for the right optical path, which is the identical with the second surface 12L as a reflecting surface for the left optical path. The first surface 11 has a symmetric configuration with respect to the plane of symmetry between the two eyes. The second surfaces 12R (13L) and 12L (13R) have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the side of the optical path distributing prism 10 remote from the observer.

[0043] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The incident light is incident on the second surface 12R as a reflecting surface for the right optical path and totally reflected by the second surface 12R. The reflected light passes through the transmitting surface 13R (12L) for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R at an incident angle not less than the critical angle and thus totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0044] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing three reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In a case where no intermediate image is formed, it is difficult to ensure the required back focus, and a wide field angle cannot be obtained. In the case of this example, however, because an intermediate image is formed once, it is possible to correct aberrations favorably even at a wide field angle. In addition, because the exit surfaces of the optical path distributing prism 10 are also used as reflecting surfaces, the number of effective surfaces of the optical path distributing prism 10 is only three. Therefore, the production is very easy. Furthermore, because the image display device 3 is located away from the observer, it does not interfere with the observer's nose. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JP(A) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 12R and 12L of the optical path distributing prism 10, it becomes possible to correct decentration aberrations very favorably.

[0045] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be made compact. Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0046] Fig. 6 shows a horizontal section (YZ-section) of Example 6. Example 6 uses an optical path distributing prism 10 formed from a decentered prism member with six surfaces in place of the optical path distributing prism 10 formed from a decentered prism member with five surfaces in Examples 3 and 4. The decentered prism members 2L and 2R for the left and right eyes are the same as those in Examples 1 to 5.

[0047] The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes. The optical path distributing prism 10 has six surfaces: a first surface 11 as a transmitting surface located on the observer side of the image display device 3; a second surface 12R as a reflecting surface facing the first surface 11 and also

facing the observer; a third surface 13R as a reflecting surface for the right optical path and a third surface 13L as a reflecting surface for the left optical path, which are located at both sides of the first surface 11 on the observer side thereof; and a fourth surface 14L as a transmitting surface for the left optical path and a fourth surface 14R as a transmitting surface for the right optical path, which are located on both sides between the second surface 12 and the third surfaces 13R and 13L. The first surface 11 and the second surface 12 each have a symmetric configuration with respect to the plane of symmetry between the two eyes. The third surfaces 13R and 13L and the fourth surfaces 14L and 14R have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the side of the optical path distributing prism 10 remote from the observer.

[0048] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10, which is common to the left and right. The incident light is reflected by the second surface 12, which is common to the left and right. The reflected light is incident on the third surface 13R as a reflecting surface for the right optical path and reflected by the third surface 13R. The reflected light passes through the transmitting surface 14R for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R at an incident angle not less than the critical angle and thus totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0049] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing four reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In a case where no intermediate image is formed, it is difficult to ensure the required back focus, and a wide field angle cannot be obtained. In the case of this example, however, because an intermediate image is formed once, it is possible to correct aberrations favorably even at a wide field angle. In addition, because the optical path distributing prism 10 is arranged to reflect light twice therein, it is possible to correct decentration aberrations very favorably. Furthermore, because the image display device 3 is located away from the observer, it does not interfere with the observer's nose. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JP(A) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 12, 13R and 13L of the optical path distributing prism 10, it becomes possible to correct decentration aberrations very favorably.

[0050] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be made compact. Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0051] Fig. 7 shows a horizontal section (YZ-section) of Example 7. In Example 7, a decentered prism member 2R constituting an optical system for the right eye and a decentered prism member 2L constituting an optical system for the left eye have the same configuration and are placed in symmetry with respect to the plane of symmetry between the two eyes. The decentered prism member 2R and the decentered prism member 2L each have, in order in which rays pass, a first surface 21R (21L), a second surface 22R (22L), a third surface 23R (23L), a fourth surface 24R (24L), and a fifth surface 25R (25L). The third surface 23R (23L) and the fifth surface 25R (25L) are the identical surface. The identical surface serves as both a totally reflecting surface and a transmitting surface.

[0052] The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes as in the case of Example 4 (Fig. 4). The optical path distributing prism 10 has five surfaces: a first surface 11 as a transmitting surface located on the observer side of the image display device 3; a third surface 13R as a transmitting surface for the right optical path and a third surface 13L as a transmitting surface for the left optical path, which are located at both sides of the first surface 11 on the observer side thereof; and a second surface 12L as a reflecting surface for the left optical path and a second surface 12R as a reflecting surface for the right optical path, which are located on the observer sides of the third surfaces 13R and 13L, respectively. The first surface 11 has a symmetric configuration with respect to the plane of symmetry between the two eyes. The third surfaces 13R and 13L and the second surfaces 12L and 12R have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the side of the optical path distributing prism 10 remote from the observer.

[0053] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The incident light is incident on the second surface 12R as a reflecting surface for the right optical path and reflected by the second surface 12R. The reflected light passes through the transmitting surface 13R for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is reflected by the second surface 22R, and the reflected light is incident on the third surface 23R at an incident angle not less than the critical angle and thus totally reflected by the third surface 23R. The reflected light is incident on the fourth surface 24R and back-reflected thereby so as to be incident on the fifth surface 25R at an incident angle less than the critical angle. The incident light is refracted by the fifth surface 25R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path

from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0054] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing four reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In a case where no intermediate image is formed, it is difficult to ensure the required back focus, and a wide field angle cannot be obtained. In the case of this example, however, because an intermediate image is formed once, it is possible to correct aberrations favorably even at a wide field angle. In addition, because the exit surfaces and reflecting surfaces of the optical path distributing prism 10 are not surfaces shared between them, decentration aberrations can be corrected favorably. Because the reflecting surfaces 12R and 12L of the optical path distributing prism 10 do not use total reflection, it is possible to reduce the angle of incidence on the surfaces and to relax the requirement for the surface manufacturing accuracy. Furthermore, because the image display device 3 is located away from the observer, it does not interfere with the observer's nose. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JP(A) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 12R and 12L of the optical path distributing prism 10, it becomes possible to correct decentration aberrations very favorably.

[0055] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be made compact. Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0056] Fig. 8 shows a horizontal section (YZ-section) of Example 8. Example 8 uses an optical path distributing prism 10 formed from a decentered prism member with three surfaces as in the case of Example 5 (Fig. 5), in place of the optical path distributing prism 10 formed from a decentered prism member with five surfaces in Example 7. The decentered prism members 2L and 2R for the left and right eyes are the same as those in Example 7.

[0057] The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes as in the case of Example 5 (Fig. 5). The optical path distributing prism 10 has three surfaces: a first surface 11 as a transmitting surface located on the side of the image display device 3 remote from the observer; a second surface 12R as a reflecting surface for the right optical path and a second surface 12L as a reflecting surface for the left optical path, which are located at both sides of the first surface 11 on the observer side thereof and function as totally reflecting surfaces; a transmitting surface 13L for the left optical path, which is the identical with the second surface 12R as a reflecting surface for the right optical path; and a transmitting surface 13R for the right optical path, which is the identical with the second surface 12L as a reflecting surface for the left optical path. The first surface 11 has a symmetric configuration with respect to the plane of symmetry between the two eyes. The second surfaces 12R (13L) and 12L (13R) have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the observer side of the optical path distributing prism 10

[0058] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The incident light is incident on the second surface 12R as a reflecting surface for the right optical path and totally reflected by the second surface 12R. The reflected light passes through the transmitting surface 13R (12L) for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is reflected by the second surface 22R, and the reflected light is incident on the third surface 23R at an incident angle not less than the critical angle and thus totally reflected by the third surface 23R. The reflected light is incident on the fourth surface 24R and back-reflected thereby so as to be incident on the fifth surface 25R at an incident angle less than the critical angle. The incident light is refracted by the fifth surface 25R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0059] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing four reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In a case where no intermediate image is formed, it is difficult to ensure the required back focus, and a wide field angle cannot be obtained. In the case of this example, however, because an intermediate image is formed once, it is possible to correct aberrations favorably even at a wide field angle. In addition, because the exit surfaces of the optical path distributing prism 10 are also used as reflecting surfaces, the number of effective surfaces of the optical path distributing prism 10 is only three. Therefore, the production is very easy. Furthermore, because the image display device 3 is located on the observer side, the whole display apparatus does not project forward to a considerable extent. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JP(A) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 12R and 12L of the optical path distributing prism 10, it becomes possible to correct decentration aberrations very favorably.

[0060] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be

made compact. Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0061] Fig. 9 shows a horizontal section (YZ-section) of Example 9. Example 9 uses an optical path distributing prism 10 formed from a decentered prism member with six surfaces as in the case of Example 6 (Fig. 6) in place of the optical path distributing prism 10 formed from a decentered prism member with five surfaces in Example 7. The decentered prism members 2L and 2R for the left and right eyes are the same as those in Example 7.

[0062] The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes as in the case of Example 6 (Fig. 6). The optical path distributing prism 10 has six surfaces: a first surface 11 as a transmitting surface located on the side of the image display device 3 remote from the observer; a second surface 12R as a reflecting surface facing the first surface 11 on the side of the first surface 11 remote from the observer; a third surface 13R as a reflecting surface for the right optical path and a third surface 13L as a reflecting surface for the left optical path, which are located at both sides of the first surface 11 on the side thereof remote from the observer; and a fourth surface 14L as a transmitting surface for the left optical path and a fourth surface 14R as a transmitting surface for the right optical path, which are located on both sides between the second surface 12 and the third surfaces 13R and 13L. The first surface 11 and the second surface 12 each have a symmetric configuration with respect to the plane of symmetry between the two eyes. The third surfaces 13R and 13L and the fourth surfaces 14L and 14R have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the observer side of the optical path distributing prism 10.

[0063] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10, which is common to the left and right. The incident light is reflected by the second surface 12, which is common to the left and right. The reflected light is incident on the third surface 13R as a reflecting surface for the right optical path and reflected by the third surface 13R. The reflected light passes through the transmitting surface 14R for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is reflected by the second surface 22R, and the reflected light is incident on the third surface 23R at an incident angle not less than the critical angle and thus totally reflected by the third surface 23R. The reflected light is incident on the fourth surface 24R and back-reflected thereby so as to be incident on the fifth surface 25R at an incident angle less than the critical angle. The incident light is refracted by the fifth surface 25R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0064] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing five reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In a case where no intermediate image is formed, it is difficult to ensure the required back focus, and a wide field angle cannot be obtained. In the case of this example, however, because an intermediate image is formed once, it is possible to correct aberrations favorably even at a wide field angle. In addition, because the optical path distributing prism 10 is arranged to reflect light twice therein, it is possible to correct decentration aberrations very favorably. Furthermore, because the image display device 3 is located on the observer side, the whole display apparatus does not project forward to a considerable extent. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JP(A) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 12, 13R and 13L of the optical path distributing prism 10 it becomes possible to correct decentration aberrations very favorably.

[0065] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be made compact. Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0066] Fig. 10 shows a horizontal section (YZ-section) of Example 10. In Example 10, a decentered prism member 2R for the right eye and a decentered prism member 2L for the left eye, which are formed from respective decentered prism members of the same configuration having three surfaces, are placed in symmetry with respect to the plane of symmetry between the two eyes, in place of the decentered prism member 2R for the right eye and the decentered prism member 2L for the left eye, which are formed from respective decentered prism members each having four surfaces in Example 8 (Fig. 8). The optical path distributing prism 10 is the same as in Example 8. Light entering the decentered prism member 2R through a first surface 21R thereof is reflected by a second surface 22R. The reflected light is refracted by a third surface 23R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye. The rest of Example 10 is the same as that in Example 8.

[0067] Fig. 11 shows a horizontal section (YZ-section) of Example 11. In Example 11, a decentered prism member 2R for the right eye and a decentered prism member 2L for the left eye, which are formed from respective decentered prism members of the same configuration having three surfaces, are placed in symmetry with respect to the plane of symmetry between the two eyes, in place of the decentered prism member 2R for the right eye and the decentered prism member 2L for the left eye, which are formed from

respective decentered prism members each having four surfaces in Example 7 (Fig. 7). The optical path distributing prism 10 is the same as in Example 7. Light entering the decentered prism member 2R through a first surface 21R thereof is reflected by a second surface 22R. The reflected light is refracted by a third surface 23R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye. The rest of Example 11 is the same as that in Example 7.

[0068] Fig. 12 shows a horizontal section (YZ-section) of Example 12. Example 12 uses an optical path distributing prism 10 formed from a decentered prism member having seven surfaces. A decentered prism member 2R constituting an optical system for the right eye and a decentered prism member 2L constituting an optical system for the left eye have the same configuration and are placed in symmetry with respect to the plane of symmetry between the two eyes. The decentered prism member 2R and the decentered prism member 2L each have, in order in which rays pass, a first surface 21R (21L), a second surface 22R (22L), a third surface 23R (23L), and a fourth surface 24R (24L).

[0069] The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes. The optical path distributing prism 10 has seven surfaces: a first surface 11 as a transmitting surface located on the side remote from the observer; a third surface 13R as a reflecting surface for the right optical path and a third surface 13L as a reflecting surface for the left optical path, which are located at both sides of the first surface 11 on the side remote from the observer; a fourth surface 14L as a transmitting surface for the left optical path and a fourth surface 14R as a transmitting surface for the right optical path, which are located on the observer sides of the third surfaces 13R and 13L, respectively; and a second surface 12L as a reflecting surface for the left optical path and a second surface 12R as a reflecting surface for the right optical path, which are located on the observer sides of the fourth surfaces 14R and 14L. The first surface 11 has a symmetric configuration with respect to the plane of symmetry between the two eyes. The third surfaces 13R and 13L, the fourth surfaces 14L and 14R and the second surfaces 12L and 12R have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the side of the optical path distributing prism 10 remote from the observer.

[0070] In the above-described arrangement, the left and right optical paths, which are shown by the dashed lines, are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The incident light is incident on the second surface 12R as a reflecting surface for the right optical path and reflected by the second surface 12R. The reflected light is incident on the third surface 13R as the subsequent reflecting surface for the right optical path and reflected by the third surface 13R. The reflected light passes through the transmitting surface 14R for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R and back-reflected thereby. The reflected light is incident on the third surface 23R and back-reflected thereby. The reflected light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0071] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing four reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably corrected for various aberrations, e.g. curvature of field and chromatic aberration. In a case where no intermediate image is formed, it is difficult to ensure the required back focus, and a wide field angle cannot be obtained. In the case of this example, however, because an intermediate image is formed once, it is possible to correct aberrations favorably even at a wide field angle. In addition, because the exit surfaces and reflecting surfaces of the optical path distributing prism 10 are not surfaces shared between them, decentration aberrations can be corrected favorably. Because the reflecting surfaces 12R, 12L, 13R and 13L of the optical path distributing prism 10 do not use total reflection, it is possible to reduce the angle of incidence on the surfaces and to relax the requirement for the surface manufacturing accuracy. Furthermore, because the image display device 3 is located away from the observer, it does not interfere with the observer's nose. In addition, it is possible to lead a display image from a single common image display device 3 to the two eyes as a bright image because the apparatus does not employ a half-mirror as is used in JP(A) 9-61748. In addition, by using free-form surfaces for the reflecting surfaces 12R, 12L, 13R and 13L of the optical path distributing prism 10, it becomes possible to correct decentration aberrations very favorably.

[0072] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be made compact. Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0073] In this example, none of the optical path distributing prism 10 and the decentered prism members 2R and 2L use a totally reflecting surface. When a totally reflecting surface is used, the incident angle of light rays needs to be increased greatly in order to satisfy the condition for total reflection. However, when a power is given to a surface having a large incident angle, decentration aberrations occur to a considerable extent. Therefore, only a weak power can be given to such a surface. In this example, which does not use such a totally reflecting surface, however, powers can be distributed equally to various surfaces by utilizing ordinary reflection. Thus, it is possible to correct decentration aberrations very favorably. In addition, because the optical path is arranged to cross itself within each of the decentered prisms 10 2R and 2L, it is possible to increase the optical path length of the ocular prism. Therefore, an intermediate image can be formed at a position within the ocular prism. Accordingly, it is possible to lengthen the overall distance from the intermediate image to the display device and to set a weak power for the optical path distributing prism 10. Consequently, it is possible to ensure favorable image-forming performance.

[0074] Examples 13 to 15 are examples relating to an illuminating optical system for the image display device 3. Example 13 shown in Fig. 13 is an example in which a transmission type LCD (liquid crystal display device) is used as the image display device 3 in the arrangement of the left and right optical systems in Example 5 shown in Fig. 5, and illuminating light sources 6R and 6L for the right and left optical paths are placed at the back of the image display device 3 (on the side remote from the optical path distributing prism 10), and further a condensing Fresnel lens 7 is placed between the image display device 3 and the light sources 6R and 6L.

[0075] In this example, illuminating light from the illuminating light source 6L for the left optical path is incident on the image display device 3 after being condensed by the Fresnel lens 7. Display light from the image display device 3 reaches the observer's left eye EL through the optical path for the left eye in Fig. 5 and projects an enlarged image of the image display device 3. Illuminating light from the illuminating light source 6R for the right optical path is incident on the image display device 3 after being condensed by the Fresnel lens 7. Display light from the image display device 3 reaches the observer's left eye ER through the optical path for the right eye in Fig. 5 and projects an enlarged image of the image display device 3.

[0076] In this case, the left and right optical systems share the illuminating optical system 7 for the left and right eyes, which is used for a single image display device (LCD) 3 common to the left and right, and the optical path distributing prism 10. Thus, it is possible to reduce the number of optical members and also possible to obtain a compact, lightweight and bright display apparatus. It should be noted that, in this example, a half-mirror is not used in the illuminating optical system either, and it is therefore possible to display a very bright image.

[0077] Example 14 shown in Fig. 14 is an example in which a reflection type LCD (liquid crystal display device) 3' is used as the image display device 3 in the arrangement of the left and right optical systems in Example 6 shown in Fig. 6. In addition, illuminating light sources 6R and 6L for the right and left optical paths are placed so as to be capable of illuminating the reflection type LCD 3' across the optical path distributing prism 10, and the second surface 12 of the optical path distributing prism 10 is formed as a half-mirror surface or a mirror surface partly provided with holes for passing light, thereby illuminating the reflection type LCD 3' with illuminating light from the light sources 6R and 6L through the second surface 12 and the first surface 11.

[0078] In this example, illuminating light from the illuminating light source 6L for the left optical path passes through the half-mirror surface, which forms the second surface 12 of the optical path distributing prism 10, or through the holes of the mirror surface partly provided with holes for passing light, which forms the second surface 12 of the optical path distributing prism 10. Then, the illuminating light crosses the optical path distributing prism 10 and passes through the first surface 11 thereof so as to be incident on the display surface of the reflection type LCD 3'. Display light reflected from the display surface reaches the observer's left eye EL through the optical path for the left eye in Fig. 6 and projects an enlarged image of the image display device 3. Similarly, illuminating light from the illuminating light source 6R for the right optical path passes through the half-mirror surface, which forms the second surface 12 of the optical path distributing prism 10 or through the holes of the mirror surface partly provided with holes for passing light, which forms the second surface 12 of the optical path distributing prism 10. Then, the illuminating light crosses the optical path distributing prism 10 and passes through the first surface 11 thereof so as to be incident on the display surface of the reflection type LCD 3'. Display light reflected from the display surface reaches the observer's right eye ER through the optical path for the right eye in Fig. 6 and projects an enlarged image of the image display device 3.

[0079] In this case, the left and right optical systems share the illuminating optical system for the left and right eyes, which is used for a single reflection type LCD 3' common to the left and right, and the optical path distributing prism 10. Thus, it is possible to reduce the number of optical members and also possible to obtain a compact, lightweight and bright display apparatus. It should be noted that, in this example, the optical path distributing prism (also used as an illuminating prism) 10 has six effective surfaces, and it is therefore possible to illuminate the reflection type LCD 3' uniformly and to correct decentration aberrations even more favorably.

[0080] Example 15 shown in Fig. 15 is an example in which a reflection type LCD 3' is used as the image display device 3 in the arrangement of the left and right optical systems in Example 4 shown in Fig. 4. In addition, illuminating light sources 6R and 6L for the left and right optical paths are placed so as to be capable of illuminating the reflection type LCD 3' across the optical path distributing prism 10, and the second surfaces 12L and 12R of the optical path distributing prism 10 for the left and right optical paths are formed as half-mirror surfaces or mirror surfaces partly provided with holes for passing light, thereby illuminating the reflection type LCD 3' with illuminating light from the light sources 6R and 6L through the second surfaces 12L and 12R and the first surface 11.

[0081] In this example, illuminating light from the illuminating light source 6L for the left optical path passes through the half-mirror surface, which forms the second surface 12R of the optical path distributing prism 10 for the optical path for the right eye, or through the holes of the mirror surface partly provided with holes for passing light, which forms the second surface 12R. Then, the illuminating light crosses the optical path distributing prism 10 and passes through the first surface 11 thereof so as to be incident on the display surface of the reflection type LCD 3'. Display light reflected from the display surface reaches the observer's left eye EL through the optical path for the left eye in Fig. 4 and projects an enlarged image of the image display device 3. Similarly, illuminating light from the illuminating light source 6R for the right optical path passes through the half-mirror surface, which forms the second surface 12L of the optical path distributing prism 10 for the optical path for the left eye, or through the holes of the mirror surface partly provided with holes for passing light, which forms the second surface 12L. Then, the illuminating light crosses the optical path distributing prism 10 and passes through the first surface 11 thereof so as to be incident on the display surface of the reflection type LCD 3'. Display light reflected from the display surface reaches the observer's right eye ER through the optical path for the right eye in Fig. 4 and projects an enlarged image of the image display device 3.

[0082] In this case, the left and right optical systems share the illuminating optical system for the left and right eyes, which is used for a single reflection type LCD 3' common to the left and right, and the optical path distributing prism 10. Thus, it is possible to reduce the number of optical members and also possible to obtain a compact, lightweight and bright display apparatus. It should be noted that, in this example, the left and right optical systems share the entrance and exit surfaces of the illuminating optical system while sharing the optical path distributing prism 10 and the illuminating optical system, thereby allowing the optical path distributing prism 10 to be reduced in both size and weight.

[0083] It should be noted that a transmission or reflection type image display device 3 can be illuminated not only in the examples shown in Figs. 4 to 6 but also in the other examples described above by using illuminating light sources 6R and 6L for the right and left optical paths, placing a condensing Fresnel lens 7, or forming a reflecting surface as a half-mirror surface or a mirror surface partly provided with holes for passing light, as shown in Figs. 13 to 15.

[0084] Incidentally, it is desirable to use surfaces with a rotationally asymmetric curved surface configuration that corrects decentration aberrations as the reflecting surfaces 1R and 1L of the optical path distributing mirror 1, the surfaces 11, 12, 12R, 12L, 13R, 13L, 14R and 14L of the optical path distributing prism 10, the surfaces 21R to 25R of the decentered prism member 2R of the ocular optical system for the right eye, and the surfaces 21L to 25L of the decentered prism member 2L of the ocular optical system for the right eye.

[0085] Basically, the decentered prism member 2R for the right eye, the decentered prism member 2L for the left eye, the optical path distributing prism 10 and the optical path distributing mirror 1 in the present invention are decentered optical systems. It is desirable that these decentered optical systems be arranged so as to include at least one optical surface with a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

[0086] In a case where a decentered optical system is used, for example, as a viewing optical system of a head-mounted image display apparatus, it is necessary in order to eliminate a dead space and minimize the overall size of the apparatus to position an image display device and each optical surface constituting the decentered optical system so that the constituent elements are accommodated in the apparatus in as compact a form as possible. Consequently, the optical system must inevitably be decentered three-dimensionally, and this causes rotationally asymmetric aberration to occur. It is impossible to correct the rotationally asymmetric aberration by only a rotationally symmetric optical system. The best surface configuration for correcting the rotationally asymmetric aberration due to three-dimensional decentration is a rotationally asymmetric surface. Therefore, in the image display apparatus according to the present invention, it is desirable to use a rotationally asymmetric curved surface configuration that corrects decentration aberrations as the configuration of at least one surface, preferably at least one reflecting surface, among the reflecting surfaces 1R and 1L of the optical path distributing mirror 1, the surfaces 11, 12, 12R, 12L, 13R, 13L, 14R and 14L of the optical path distributing prism 10 the surfaces 21R to 25R of the decentered prism member 2R of the ocular optical system for the right eye and the surfaces 21L to 25L of the decentered prism member 2L of the ocular optical system for the right eye.

[0087] A free-form surface used in the present invention as a surface with a rotationally asymmetric curved surface configuration is defined by the following equation. The Z-axis of the defining equation is the axis of a free-form surface. EMI59.1

[0088] In the equation (a), the first term is a spherical surface term, and the second term is a free-form surface term.

[0089] In the spherical surface term: c: the curvature at the vertex k: a conic constant r= 2ROOT (X<2>+Y<2>)

[0090] The free-form surface term is given by EMI59.2 EMI60.1 where Cj (j is an integer of 2 or higher) are coefficients.

[0091] In general, the above-described free-form surface does not have planes of symmetry in both the XZ- and YZ-planes. However, a free-form surface having only one plane of symmetry parallel to the YZ-plane is obtained by making all terms of odd-numbered degrees with respect to X zero. A free-form surface having only one plane of symmetry parallel to the XZ-plane is obtained by making all terms of odd-numbered degrees with respect to Y zero.

[0092] In addition, free-form surfaces as the above-described surfaces with a rotationally asymmetric curved surface configuration may be defined by Zernike polynomials. That is, the configuration of a free-form surface may be defined by the following equation (b). The Z-axis of the defining equation (b) is the axis of Zernike polynomial. A rotationally asymmetric surface is defined by polar coordinates of the height of the Z-axis with respect to the XY-plane. In the equation (b), A is the distance from the Z-axis in the XY-plane, and R is the azimuth angle about the Z-axis, which is expressed by the angle of rotation measured from the Z-axis. x=R x cos(A) y=R x sin(A) "(b)" Z=D2 +D3Rcos(A)+D4Rsin(A) +D5R<2>cos(2A)+D6(R<2>-1) +D7R<2>sin(2A) +D8R<3>cos(3A)+D9(3R<3>-2R)cos (A) +D10(3R<3>-2R)sin(A)+D11R<3>sin(3A) +D12R<4>cos(4A)+D13(4R<4>-3R<2>)cos(2A) +D14(6R<4>-6R<2>+1)+D15(4R<4>-3R<2>)sin(2A) +D16R<4>sin(4A) +D17R<5>cos(5A)+D18(5R<5>-4R<3>)cos(3A) +D19(10R<5>-12R<3>+3R)cos(A) +D20 (10R<5>-12R<3>+3R)sin(A) +D21(5R<5>4R<3>) sin(3A)+D22R<5>sin(5A) +D23R<6>cos(6A)+D24 (6R<6>-5R<4>)cos(4A) +D25(15R<6>-20R<4>+6R<2>)cos (2A) +D26(20R<6>-30R<4>+12R<2>-1) +D27 (15R<5>-20R<4>+6R<2>) sin(2A) +D28(6R<6>-5R<4>)sin(4A)+D29R<6>sin(6A) where Dm (m is an integer of 2 or higher) are coefficients.

[0093] It should be noted that to design an optical system symmetric with respect to the X-axis direction, D4, D5, D6, D10,D11 D12, D13,D14,D20, D21, D22. should be used.

[0094] The above defining equations are shown to exemplify surfaces with a rotationally asymmetric curved surface configuration. Therefore, the same advantageous effect can be obtained for any other defining equation that expresses such a rotationally asymmetric surface.

[0095] When a light ray connecting the center of the display image of the image display device and the center of the pupil is defined as an optical axis, it is desirable that the free-form surfaces of the optical path distributing mirror 1, the optical path distributing prism 10, the ocular prism member 2R for the right eye and the ocular prism member 2L for the right eye have only one plane of symmetry in a plane (YZ-plane) containing the optical axis in the folded optical path within each prism.

[0096] It should be noted that other examples of defining equations for free-form surfaces include the following defining equation (c): Z= SIGMA SIGMA nmXY

[0097] Assuming that k=7 (polynomial of degree 7), for example, a free-form surface is expressed by an expanded form of the above equation as follows: "(c)" Z=C2 +C3Y+C4 ¦X¦ +C5Y<2>+C6Y ¦X¦ +C7X<2> +C8Y<3>+C9Y<2> ¦x¦ +C10YX<2>+C11 ¦X<3>¦ +C12Y<4>+C13Y<3> ¦X¦ +C14Y<2>X<2>+C15Y ¦X<3>¦ +C16X<4> +C17Y<5>+C18Y<4> ¦X¦ +C19Y<3>X<2>+C20Y<2> ¦X<3>¦ +C21YX<4>+C22 ¦X<5>¦ +C23Y<6>+C24Y<5> ¦X¦ +C25Y<4>X<2>+C26Y<3> ¦X<3>¦ +C27Y<2>X<4>+C28Y¦X<5>¦ +C29X<6> +C30Y<7>+C31Y<6> ¦X¦+C32Y<5>X<2>+C33Y<4> ¦X<3>¦ +C34Y<3>X<4>+C35Y<2> ¦X<5>¦+C36YX<6>+C37 ¦X<7>¦

[0098] It should be noted that the refracting surfaces of the ocular prisms 2L and 2R for the left and right eyes that are closest to the respective exit pupils (the surfaces 24L and 24R in Examples 1 to 6; the surfaces 25L and 25R in Examples 7 to 9; and the surfaces 23L and 23R in Examples 10 and 11) may be formed from rotationally symmetric aspherical surfaces. In this case, productivity improves. In addition, when the rotationally symmetric aspherical surface is used as a reference surface, positioning of other surfaces is facilitated.

[0099] Further, other known types of decentered prism members may be used as the decentered prism members 2L and 2R, which constitute the optical systems for the left and right eyes in the foregoing examples.

[0100] Next, image display apparatuses according to Examples 16 to 30 will be described as specific numerical examples of the present invention.

[0101] Fig. 16 is a diagram for describing the image display apparatus according to Example 16, in which: Fig. 16(a) is a horizontal sectional view (YZ-section) showing optical systems for two eyes; and Fig. 16(b) is a horizontal sectional view showing only the optical system for the right eye. Regarding the following Examples 17 to 28, horizontal sectional views of optical systems for two eyes, which are similar to Fig. 16 (a), are shown in Figs. 17 to 27.

[0102] In any of the examples, the optical systems have configurations that are symmetric with respect to the plane of symmetry between the two eyes as in the case of the above-described Examples 1 to 15. Therefore, only constituent parameters in the backward ray tracing of the optical system for the right eye as shown in Fig. 16(b) will be shown later. Regarding the constituent parameters in the backward ray tracing in Examples 16 to 28 (described later), as shown in Fig. 16(b), an axial principal ray (optical axis) O is defined by a light ray passing through the center of the exit pupil 4R of the optical system at right angles thereto and reaching the center of the image display device 3. In the backward ray tracing, the center of the pupil 4R is defined as the origin of decentered optical surfaces of a decentered optical system. A Z-axis is taken in the direction of the axial principal ray O, and the direction in which the Z-axis extends from the pupil 4R toward the final surface of the optical system (the first surface in the backward ray tracing: entrance surface; in Fig. 16(b), the fourth surface 24R) is defined as a positive direction of the Z-axis. A plane containing the Z-axis and the center of the image display device 3 is defined as a YZ-plane. An axis extending through the origin at right angles to the YZ-plane is defined as an X-axis, and the direction in which the X-axis extends from the obverse side toward the reverse side of the plane of the figure is defined as a positive direction of the X-axis. An axis that constitutes a right-handed orthogonal coordinate system in combination with the X- and Z-axes is defined as a Y-axis. In Fig. 16(b), this coordinate system is shown. Illustration of the coordinate system is omitted in Figs. 17 to 27, which show Examples 17 to 28.

[0103] In Examples 16 to 30, decentration of each surface is made in the YZ-plane, and the one and only plane of symmetry of each rotationally asymmetric free-form surface is the YZ-plane.

[0104] Regarding decentered surfaces, each surface is given displacements in the X-, Y- and Z-axis directions (X, Y and Z, respectively) of the vertex position of the surface from the origin of the above-described coordinate system, and tilt angles (degrees) of the center axis of the surface [the Z-axis of the above equation (a) in regard to free-form surfaces; the Z-axis of the following equation (d) in the case of aspherical surfaces] with respect to the X-, Y- and Z-axes (alpha , beta and gamma , respectively). In this case, the positive alpha and (beta mean counterclockwise rotation relative to the positive directions of the corresponding axes, and the positive gamma means clockwise rotation relative to the positive direction of the Z-axis.

[0105] Among optical functional surfaces constituting the optical system in each example, a specific surface and a surface subsequent thereto are given a surface separation when these surfaces form a coaxial optical system. In addition, the refractive index and Abbe's number of each medium are given according to the conventional method.

[0106] The configuration of each free-form surface used in the present invention is defined by the above equation (a). The Z-axis of the defining equation is the axis of the free-form surface.

[0107] Aspherical surfaces are rotationally symmetric aspherical surfaces given by the following equation: "(d)" $Z=(Y^{2}/R)/[1+\{1-(1+K)Y^{2}/R^{2}\}^{1/2}]+AY^{4}+BY^{6}+CY^{8}+DY^{10}+$.

[0108] In the above equation, Z is an optical axis (axial principal ray) for which the direction of travel of light is defined as a positive direction, and Y is taken in a direction perpendicular to the optical axis. R is a paraxial curvature radius, K is a conic constant, and A, B, C, D are 4th-, 6th-, 8th- and 10th-order aspherical coefficients, respectively. The Z-axis of this defining equation is the axis of the rotationally symmetric aspherical surface.

[0109] It should be noted that those terms concerning free-form surfaces and aspherical surfaces for which no data is shown are zero. The refractive index is expressed by the refractive index for the spectral d-line (wavelength: 587.56 nanometers). Lengths are given in millimeters.

[0110] In addition, other examples of defining equations for free-form surfaces include Zernike polynomials given by the above equation (b).

[0111] Although in the examples of the present invention the surface configuration is expressed by a free-form surface using the above equation (a), it should be noted that the same advantageous effect can be obtained by using the above equation (b) or (c), as a matter of course.

[0112] Referring back to Fig. 16(a), a major difference between Example 16 and Example 4 is in the optical path distributing prism 10. The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes. The optical path distributing prism 10 has five surfaces: a first surface 11 as a transmitting surface located on the side of the image display device 3 remote from the observer; a third surface 14R as a transmitting surface for the right optical path and a third surface 14L as a transmitting surface for the left optical path, which are located at both sides of the first surface 11 on the side remote from the observer; and a second surface 12R as a reflecting surface for the right optical path and a second surface 12L as a reflecting surface for the left optical path, which are located on the sides of the fourth surfaces 14R and 14L remote from the observer. The fourth surface 14R as a transmitting surface for the right optical path and the fourth surface 14L as a transmitting surface for the left optical path are identical with the third surface 13L as a reflecting surface for the left optical path and the third surface 13R as a reflecting surface for the right optical path, respectively. The identical surfaces each serve as both a transmitting surface and a totally reflecting surface. The first surface 11 has a symmetric configuration with respect to the plane of symmetry between the two eyes. The fourth surfaces 14R and 14L and the second surfaces 12R and 12L have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the observer side of the optical path distributing prism 10.

[0113] In the above-described arrangement, the left and right optical paths are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The incident light is incident on the second

surface 12R as a reflecting surface for the right optical path and reflected by the second surface 12R. Then, the reflected light is incident on the third surface 13R as a reflecting surface for the right optical path, which serves also as the transmitting surface 14L for the left optical path, and reflected by the third surface 13R. The reflected light passes through the transmitting surface 14R for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R at an incident angle not less than the critical angle and thus totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0114] Example 17 shown in Fig. 17 is similar to Example 1 in Fig. 1 but different from Example 1 in the arrangement of the optical path distributing mirror 1 at the middle between the two eyes. In the case of this example, a reflecting surface 1R for the right optical path and a reflecting surface 1L for the left optical path, which have symmetric configurations with respect to the plane of symmetry between the two eyes, are formed from back-coated mirrors produced by coating the back surfaces of lenses 8R and 8L. The rest of Example 17 is the same as that in Example 1.

[0115] In the above-described arrangement, the left and right optical paths are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes, first, enters the lens 8R for the right optical path, which constitutes the optical path distributing mirror 1, through the entrance surface 11L. The light is reflected by the reflecting surface 1R to exit from the entrance surface 11L and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism The light is incident on the second surface 22R at an incident angle not less than the critical angle and thus totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. It should be noted that no intermediate image is formed in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0116] Example 18 shown in Fig. 18 is similar to Example 4 in Fig. 4.

[0117] Example 19 shown in Fig. 19 is similar to Example 5 in Fig. 5.

[0118] Example 20 shown in Fig. 20 is similar to Example 6 in Fig. 6.

[0119] Fig. 21 shows Example 21. A major difference between Example 21 and Example 6 is in the optical path distributing prism 10. The optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to the plane of symmetry between the two eyes. The optical path distributing prism 10 has seven surfaces: a first surface 11 as a transmitting surface located on the observer side of the image display device 3; a second surface 12R as a reflecting surface for the right optical path and a second surface 12L as a reflecting surface for the left optical path, which are reflecting surfaces facing the first surface 11 and also facing the observer; a third surface 13R as a reflecting surface for the right optical path and a third surface 13L as a reflecting surface for the left optical path, which are disposed at both sides of the first surface 11 on the observer side thereof; and a fourth surface 14L as a transmitting surface for the left optical path and a fourth surface 14R as a transmitting surface for the right optical path, which are disposed on both sides between the third surfaces 13R and 13L and the second surfaces 12R and 12L, respectively. The first surface 11 has a symmetric configuration with respect to the plane of symmetry between the two eyes. The second surfaces 12R and 12L, the third surfaces 13R and 13L and the fourth surfaces 14R and 14L have configurations that are symmetric with respect to the plane of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the side of the optical path distributing prism 10 remote from the observer.

[0120] In the above-described arrangement, the left and right optical paths are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The incident light is incident on the second surface 12R as a reflecting surface for the right optical path and reflected by the second surface 12R. Then, the reflected light is incident on the third surface 13R and reflected thereby. The reflected light passes through the transmitting surface 14R for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R at an incident angle not less than the critical angle and thus totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0121] Example 22 shown in Fig. 22 is similar to Example 21 in Fig. 21 but different from Example 21 in that ocular lenses 9R and 9L are placed between the exit surfaces 24R and 24L of the decentered prism members 2R and 2L for the right and left eyes, which constitute ocular optical systems, and the exit pupils 4R and 4L for the right and left eyes, respectively.

[0122] Example 23 shown in Fig. 23 is similar to Example 2 in Fig. 2.

[0123] Example 24 shown in Fig. 24 is similar to Example 2 in Fig. 2 but different therefrom in that the negative lens 5 is formed from a cemented lens.

[0124] Fig. 25 shows Example 25. A major difference between Example 25 and Example 1 is as follows. The optical path distributing mirror 1 at the middle between the two eyes has four reflecting surfaces, i.e. a reflecting surface 1R for the right optical path and a reflecting surface 1L for the left optical path, which have

symmetric configurations with respect to the plane of symmetry between the two eyes, and a second reflecting surface 1R' for the right optical path and a second reflecting surface IL' for the left optical path, which face the reflecting surfaces 1R and 1L, respectively. The second reflecting surfaces 1R' and 1L' have configurations that are symmetric with respect to the plane of symmetry between the two eyes. Moreover, the image display device 3 is placed on the side of the optical path distributing mirror 1 remote from the observer.

[0125] In the above-described arrangement, the left and right optical paths are symmetric with respect to the plane of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the reflecting surface 1R for the right optical path, which constitutes the optical path distributing mirror 1, and reflected by the reflecting surface 1R.Then, the light is incident on the second reflecting surface 1R' for the right optical path and reflected thereby so as to enter the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism. The light is incident on the second surface 22R at an incident angle not less than the critical angle and thus totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0126] Example 26 shown in Fig. 26 is similar to Example 11 in Fig. 11.

[0127] Example 27 shown in Fig. 27 is similar to Example 7 in Fig. 7. However, the second surfaces 22L and 22R and the fourth surfaces 24L and 24R of the decentered prism members 2L and 2R constituting the ocular optical systems for the right and left eyes are formed from the identical reflecting surfaces, respectively.

[0128] Example 28 shown in Fig. 28 is similar to Example 12 in Fig. 12.

[0129] Fig. 29 is a ray path diagram showing image display apparatus according to Examples 29 and 30 of the present invention. In Fig. 29, an image display device constituting the image display device is denoted by reference numeral 3. An exit pupil for the right eye is denoted by 4R, and an exit pupil for the left eye is denoted by 4L. A decentered prism member placed in front of the right eye as an optical system for the right eye is denoted by 2R, and a decentered prism member placed in front of the left eye as an optical system for the left eye is denoted by 2L. In addition, an optical path distributing prism formed from a decentered prism member, which is placed at the middle between the two eyes, is denoted by 10. The decentered prism members 2R, 2L and 10 are made of a transparent medium having a refractive index larger than 1. In the following description, surfaces stated to be reflecting surfaces are mirror surfaces formed by providing mirror coatings on the relevant surfaces of the decentered prism members except totally reflecting surfaces.

[0130] Examples 29 and 30 are arranged as shown in Fig. 29, which shows a horizontal section (YZ-section) thereof. First, the arrangement will be described in regard to the optical path for the right eye. The triangular prism-shaped optical path distributing prism 10 at the middle between the two eyes has a symmetric configuration with respect to a plane 20 of symmetry between the two eyes (i.e. a plane passing through the center of a line segment connecting the respective centers of the exit pupil 4R for the right eye and the exit pupil 4L for the left eye at right angles to the line segment). The optical path distributing prism 10 has three surfaces: a first surface 11 as a transmitting surface located on the observer side of the image display device 3; a second surface 12R as a reflecting surface for the right optical path and a second surface 12L as a reflecting surface for the left optical path, which are located at both sides of the first surface 11 on the observer side thereof to function as totally reflecting surfaces; a transmitting surface 13L for the left optical path that is the identical with the second , surface 12R as a reflecting surface for the right optical path; and a transmitting surface 13R for the right optical path that is the identical with the second surface 12L as a reflecting surface for the left optical path. The first surface 11 has a symmetric configuration with respect to the plane 20 of symmetry between the two eyes. The second surfaces 12R (13L) and 12L (13R) have configurations that are symmetric with respect to the plane 20 of symmetry between the two eyes. The image display device 3 is placed to face the first surface 11 of the optical path distributing prism 10 on the side of the optical path distributing prism 10 remote from the observer.

[0131] The decentered prism member 2R, which constitutes an optical system for the right eye, and the decentered prism member 2L, which constitutes an optical system for the left eye, have the same configuration and are placed in symmetry with respect to the plane 20 of symmetry between the two eyes. The decentered prism member 2R and the decentered prism member 2L each have, in order in which rays pass, a first surface 21R (21L), a second surface 22R (22L), a third surface 23R (23L), and a fourth surface 24R (24L). The second surface 22R (22L) and the fourth surface 24R (24L) are the identical surface. The identical surface serves as both a totally reflecting surface and a transmitting surface.

[0132] In the above-described arrangement, the left and right optical paths are symmetric with respect to the plane 20 of symmetry between the two eyes. Therefore, the optical path for the right eye will be described representatively. Display light from a single image display device 3 common to the two eyes is, first, incident on the first surface 11 of the optical path distributing prism 10. The light is incident on the second surface 12R as a reflecting surface for the right optical path and totally reflected by the second surface 12R. The reflected light passes through the transmitting surface 13R (12L) for the right optical path and enters the decentered prism member 2R. The incident light passes through the first surface 21R to enter the prism and is incident on the second surface 22R at an incident angle not less than the critical angle, thereby being totally reflected by the second surface 22R. The reflected light is incident on the third surface 23R and back-reflected thereby so as to be incident on the fourth surface 24R at an incident angle less than the critical angle. The incident light is refracted by the fourth surface 24R to exit from the decentered prism member 2R. Then, the light is led to the exit pupil 4R for the right eye to project an enlarged image of the image display device 3 into the observer's right eye. In this case, an intermediate image is formed once in the optical path from the image display device 3 to the exit pupil 4R. The optical path for the left eye is in symmetric relation to the optical path for the right eye with respect to the plane 20 of symmetry between the two eyes as in the case of the arrangement of the optical system for the right eye.

[0133] With the above-described arrangement, in both the left and right optical paths, display light from the image display device 3 is led to the eyeball after undergoing three reflections. Therefore, images led to the left and right eyes are not in mirror-image relation to each other. Accordingly, it is possible to see images of the same orientation with the left and right eyes. Moreover, because the image of the image display device 3 is projected via reflecting and transmitting surfaces which are decentered or tilted with respect to the optical axis and at least one of which has a positive power, it is possible to project an image favorably

corrected for various aberrations, e.g. curvature of field and chromatic aberration.

[0134] Further, in both the left and right optical paths, the greater part of the optical path passes through the decentered prism members 10 and 2R (2L), which are filled with a transparent medium having a refractive index larger than 1, and the optical path is folded therein. Therefore, the whole ocular optical system can be made compact.

[0135] Furthermore, the decentered prism members 2R and 2L are placed at positions that are in plane symmetry with each other and have the same configuration. It is only necessary to prepare two decentered prism members 2R and 2L having the same configuration and to place them at respective positions that are in plane symmetry with respect to the decentered prism member 10 at the middle between the two eyes.

[0136] It is premised that an image display device 3 having wide viewing angle characteristics is used in the above-described optical system. Therefore, it is desirable to use a spontaneous light-emission type organic EL (see Fig. 40) for the image display device 3. When a transmission type LCD (liquid crystal display device) is used, it is desirable to insert a DOE (diffractive optical element) between the LCD and the backlight to thereby illuminate the LCD with +/-1st-order light, or to use an LCD with viewing angle characteristics widened by using such scattering film that the viewing angle is increased (the same is the case with Examples 1 to 30).

[0137] Incidentally, it is desirable that the angle alpha of reflection of display light at the second surfaces 12R and 12L of the optical path distributing prism 10 for distributing the display image of the image display device 3 to the optical path for the right eye and the optical path for the left eye, as shown in Fig. 30 (only the optical path for the right eye is shown in Fig. 30, for the sake of simplicity, because the optical path for the right eye and the optical path for the left eye are in plane-symmetric relation to each other in the image display apparatus according to the present invention), satisfy the following condition: "(1)" 33 DEG </= alpha </=70 DEG

[0138] If alpha is smaller than the lower limit of this condition, i.e. 33 DEG , rays are not reflected by the second surfaces 12R and 12L but pass therethrough, thus failing, to form an image. If alpha exceeds the upper limit, i.e. 70 DEG , it is difficult for rays to travel along the above-described optical paths in the arrangement of this optical system. Consequently, the rays fail to form an image.

[0139] If is more desirable to satisfy the following condition: "(1-1)" 40 DEG </= alpha </=60 DEG

[0140] The meaning of the upper and lower limits of this condition is the same as that of the above-described condition (1).

[0141] Next, it is desirable that the angle beta formed between a plane 20 passing through the center of a line segment connecting the center of the exit pupil 4R for the right eye and the center of the exit pupil 4L for the left eye at right angles to the line segment (the plane of symmetry between the two eyes) and a tangent plane 15 to the second surface 12R of the optical path distributing prism 10 at a point where the optical axis of the optical path for the right eye is incident on the second surface 12R and the angle beta formed between the plane 20 and a tangent plane to the second surface 12L of the optical path distributing prism 10 at a point where the optical axis of the optical path for the left eye is incident on the second surface 12L satisfy the following condition: "(2)" 13 DEG </= beta </=24 DEG

[0142] If beta is smaller than the lower limit of this condition, i.e. 13 DEG , some of the reflected rays do not pass through the third surface 13R but are undesirably reflected thereby, or rays are not reflected by the second surface 22R of the decentered prism member 2R but pass therethrough, undesirably. Consequently, it is difficult for rays to travel along the above-described optical paths, and the rays fail to form an image. If beta exceeds the upper limit, i.e. 24 DEG , some rays are not reflected by the second surface 12R but pass therethrough, undesirably. Consequently, it is difficult for rays to travel along the above-described optical paths, and the rays fail to form an image.

[0143] If is more desirable to satisfy the following condition: "(2-1)" 15 DEG </= beta </=22 DEG

[0144] The meaning of the upper and lower limits of this condition is the same as that of the above-described condition (2).

[0145] If is even more desirable to satisfy the following condition: "(2-2)" 17 DEG </= beta </=20 DEG

[0146] The meaning of the upper and lower limits of this condition is the same as that of the above-described condition (2).

[0147] Next, let us assume that, in backward ray tracing from the pupil side, the distance between the intersection of the ray passing through the center of the exit pupil 4R for the right eye at the maximum field angle on the right-hand side and the fourth surface 24R of the decentered prism member 2R for the right eye and the intersection of the ray passing through the center of the exit pupil 4L for the left eye at the maximum field angle on the left-hand side and the fourth surface 24L of the decentered prism member 2L for the left eye is a width L, as shown in Fig. 31, and the distance between the point closest to the left and right exit pupils among points at which bundles of rays passing through the centers of the left and right exit pupils within the overall field angle pass through or are reflected by the fourth surface 24R of the decentered prism member 2R for the right eye ER or the fourth surface 24L of the decentered prism member 2L for the left eye EL and the display surface of the image display device 3 in a direction perpendicular to the display surface is a depth D. In this case, it is desirable that the ratio of the depth D to the width L, i.e. D/L, satisfy the following condition: "(3)" 0.3</=D/L</=0.5

[0148] If D/L is smaller than the lower limit, i.e. 0.3, a wide field angle cannot be obtained. Consequently, the image field becomes unfavorably small in size. If D/L exceeds the upper limit, i.e. 0.5, the depth assumes a large value, and the optical system becomes unfavorably large in size.

[0149] It is more desirable to satisfy the following condition: "(3-1)" 0.35</=D/L</=0.45

[0150] The meaning of the upper and lower limits of this condition is the same as that of the above-described condition (3).

[0151] Regarding Examples 29 and 30, horizontal sectional views illustrating only optical systems for the right eye in these examples are shown in Figs. 32 and 33 because the optical system and optical path for the right eye and the optical system and optical path for the left eye are in plane-symmetric relation to each other as stated above. Regarding the optical system for the left eye, it is only necessary to place the surfaces of the optical system for the left eye in symmetric relation to the optical system for the right eye with respect to the plane 20 of symmetry between the two eyes (Fig. 29).

[0152] Constituent parameters in the backward ray tracing of the optical systems for the right eye in the above-described Examples 16 to 30 will be shown below. The observation field angles in these examples when arranged in the form of a viewing optical system are as follows: in Examples 16 to 21 and 23 to 28, the horizontal half field angle is 10 DEG , and the vertical half field angle is 7.5 DEG ; in Example 22, the horizontal half field angle is 12 DEG , and the vertical half field angle is 9.1 DEG ; in Example 29, the horizontal half field angle is 7 DEG , and the vertical half field angle is 5.26 DEG ; and in Example 30, the horizontal half field angle is 7.5 DEG , and the vertical half field angle is 5.64 DEG . In Examples 16 to 28, the size of the image display device is 8.9x6.7 mm. In Example 29, the image display device size is 8.94x671 mm. In Example 30, the image display device size is 8.94x671 mm. In all Examples 16 to 30, the pupil diameter is 4 mm. It should be noted that when arranged in the form of a viewing optical system, Example 29 is equivalent to an optical system with a focal length of 36 mm, and Example 30 is equivalent to an optical system with a focal length of 34 mm.

[0153] It should be noted that in the tables below, "FFS" denotes a free-form surface, and "ASS" denotes an aspherical surface, and further "RE" denotes a reflecting surface. <tb><TABLE> Columns=6 <tb>Title: Example 16 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS 1 &cir& <SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>ASS 1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS2 &cir& <SEP><SEP>(3) <tb><SEP>6<SEP>FFS3 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2 <tb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS5 &cir& (RE)<SEP><SEP>(6) <SEP>1.5254<SEP>56.2 <tb><SEP>9<SEP> INFINITY <SEP><SEP>(7) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(8)

ASS1 &cir& R -61.00 K 0.0000 A -2.8485x10<-6> B 8.9070x10<-9>

FFS1 &cir& C4 -1.2212x10<-2> C6 -1.2499x10<-2> C8 -7.2115x10<-6> C10 3.6893x10<-5> C11 -2.8593x10<-6> C13 -3.0073 x 10<-6> C15 -3.4462x10<-6> C17 -1.6344x10<-9> C19 -4.1364x10<-8> C21 -2.0345x10<-8>

FFS2 &cir& C4 1.0330x10<-2> C6 -2.2053x10<-2> C8-8.5243x10<-5>

C10-1.3497x10<-3> C111.1148x10<-4> C13 -2.6040X10<-4> C15 3.9230x10<-4>

F F S3 &cir& C4 -8.5360 x 10<-3> C6 -8. 8071 x 10<-3> C87.1801 x 10<-5> C10 7.6086x10<-5> C11 6.3213x10-7 C13 8.2333x10<-6> C15 1.9455x10<-6>

FFS4 &cir& C4 8.5360x10<-3> C6 8.8071x10<-3> C8 -7.1801x10<-5> C10 -7.6086x10<-5> C11 -6.3213x10<-7> C13 -8.2333x10<-6> C15 -1.9455x10<-6>

FFS5 &cir& C4 1.2329x10<-2> C6 6.7124x10<-3> C8 -3.9501x10<-5> C10 -1.3809x10<-4> C11 -1.6628x10<-6> C13 3.6302x10<-6> C15 -3.8832x10<-6>

Displacement and tilt(1) X 0.00 Y 9.84 Z 32.73 alpha -0.83 beta 0.00 gamma 0.00

Displacement and tilt(2)

X 0.00 Y -0.48 Z 39.28 alpha -30.61 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 16.17 Z 37.03 alpha 35.52 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 19.39 Z 46.79 alpha -91.71 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 44.61 Z 46.79 alpha -88.29 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 22.62 Z 55.56 alpha 136.79 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 32.00 Z 33.76 alpha -180.00 beta 0.00 gamma 0.00

Displacement and tilt(8) X 0.00 Y 32.00 Z 29.64 alpha -180.00 beta 0.00 gamma 0.00 <tb></TABLE> <tb><TABLE> Columns=6 <tb>Title: Example 17 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1) <SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS2 &cir& <SEP><SEP>(3) <tb><SEP>6<SEP>FFS3 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2 <tb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS3 &cir& <SEP><SEP>(4) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(6)

*ASS1 &cir& R -95.45 K 0.0000 A -6.5740x10<-8> B 1.3849x10<-9>

FFS1 &cir& C4 -1.0306x10<-2> C6 -1.0412x10<-2> C8 2.0096x10<-5> C10 2.8787x10<-5> C11 -7.7967x10<-7> C13 -2.3996x10<-6> C15 -2.6208 x 10-<6> C17 -6.0108x10<-8> C19 1.1907 x 10<-8> C21 1.4676x10<-8>

FFS2 &cir& C4 -7.5538x10<-3> C6 6696x10<-4> C8 1.3858 x 10<-3> C10 2.0287x10<-3> C11 8.0303x10<-5> C13 -1.5350x10<-4> C15 -6.5070x10<-5>

FFS3 &cir& C 4 -7.6923x10<-2> C6 -9.3217x10<-3> C8 3.8760x10<-3> C10 -9.4736x10<-4> C11 -7.2844x10<-4> C13 6.5675x10<-4> C15 -4.9359x10<-5>

FFS4 &cir& C4 -1.1587x10<-2> C6 1.1772x10<-2> C8 1.0849x10<-3> C10 -1.8206 x10<-4> C11 -5.4651 x 10<-4> C13 1.7195 x 10<-4> C15 -1.3202x10<-5>

Displacement and tilt(1) X 0.00 Y 9.05 Z 39.11 alpha 10.70 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y 0.24 Z 48.07 alpha -21.35 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 19.03 Z 43.57 alpha 92.98 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 35.65 Z 58.02 alpha -145.94 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 39.28 Z 61.80 alpha -147.29 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 38.00 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE> <tb><TABLE> Columns=6 <tb>Title: Example 18 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS2 &cir& <SEP><SEP>(3) <tb><SEP>6<SEP>FFS3 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2 <tb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS5 &cir& <SEP><SEP>(6) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(7)

ASS1 &cir& R -99.17 K 0.0000 A -5.1344x10<-6> B 5.4560x10<-9>

F F S1 &cir& C4 -1.3402x10<-2> C6 -1.1018x10<-2> C8 2.9828x10<-6> C10 -4.6829x10<-6> C11 -2.4079x10<-6> C13 -3.1115x10<-6> C15 -2.2505x10<-6> C17 1.0452x10<-7> C 19 1.1084x10<-7> C21 2.6833x10<-8>

FFS2 &cir& C 4 -1.9489x10<-2> C6 -3.8808x10<-3> C8 4.8522x10<-3> C10 4.8858x10<-3> C11 1.8575x10<-4> C13 -7.7300x10<-4> C15 -6.0291x10<-4>

FFS3 &cir& C4 -8.6443x10<-2> C6-3.9460x10<-2> C8 8.0248x10<-3> C10 9.1640 x 10<-3> C11 -6.2318x10<-5> C13 1.4493 x 10<-3> C15 1.6706x10<-3>

FFS4 &cir& C4 1.9984x10<-2> C6 1.7719x10<-2> C8 2.2720x10<-4> C10 2.2345x10<-4> C11 6.1407x10<-6> C13 2.3412x10<-5> C15 -1.4916x10<-6>

FFS5 &cir& C4 -1.0029x10<-2> C6 4.6836 x 10<-3>

Displacement and tilt(1) X 0.00 Y 12.74 Z 36.00 alpha 2.52 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y -0.37 Z 45.03 alpha -28.87 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 20.71 Z 40.51 alpha 74.60 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 22.61 Z 41.95 alpha -113.38 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 38.54 Z 52.07 alpha -144.30 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 36.77 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 32.00 Z 30.00 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE> <tb><TABLE> Columns=6 <tb>Title: Example 19 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS2 &cir& <SEP><SEP>(3) <tb><SEP>6<SEP>FFS3 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2 <tb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS5 &cir& <SEP><SEP>(6) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(7)

ASS1 &cir& R 371.46 K 0.0000 A -8.4688x10<-7> B 2.9089x10<-10>

FFS1 &cir& C 4 -6.3820x10<-3> C6 -8.9287x10<-3> C8 -7.5189x10<-5> C10 -2.7485x10<-6> C11 -5.1745x10<-6> C13 -6.0033x10<-7> C15 2.8823x10<-6> C17 3.2184x10<-7> C19 8.6382 x 10<-8> C21 -1.5498x10<-8>

FFS2 &cir& C4 -4.0226x10<-2> C6 -3.3297x10<-2> C8 2.4201x10<-3> C10 6.0781x10<-3> C11 7.4789x10<-4> C13 -3.2635x10<-4> C 15 2.1572x10<-4>

FFS3 &cir& C4 -2.0127x10<-2> C6 -1.4009x10<-2> C8 -1.3093x10<-3> C10 -1.0645x10<-4> C11 -2.3099x10<-4> C13 -2.8818x10<-5> C15 -1.4532x10<-6>

FFS4 &cir& C4 2.0127x10<-2> C61.4009x10<-2> C8 1.3093x10<-3> C10 1.0645x10<-4> C11 2.3099x10<-4> C13 2.8818x10<-5> C15 1.4532x10<-6>

FFS5 &cir& C4 2.3952x10<-1> C6 6.3371x10<-4>

Displacement and tilt(1) X 0.00 Y 20.12 Z 35.02 alpha 6.83 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y 0.52 Z 47.68 alpha -27.07 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 27.52 Z 37.59 alpha 76.08 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 29.00 Z 40.96 alpha -118.18 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 35.00 Z 40.96 alpha -61.82 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 50.73 alpha -180.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 32.00 Z 58.00 alpha -180.00 beta 0.00 gamma 0.00 <tb></TABLE> <tb><TABLE> Columns=6 <tb>Title: Example 20 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS2 &cir& <SEP><SEP>(3) <tb><SEP>6<SEP>FFS3 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2 <tb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS5 &cir& (RE)<SEP><SEP>(6)<SEP>1.5254<SEP>56.2 <tb><SEP>9<SEP>FFS6 &cir& <SEP><SEP>(7) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(8)

ASS1 &cir& R -76.87 K 0.0000 A 6.3868x10<-6> B -6.7614x10<-9>

FFS1 &cir& C4 -1.3820x10<-2> C6 -1.2744x10<-2> C8 -5.9146x10<-5> C10 -8.6079x10<-5> C11 -1.5009x10<-6> C13 -3.9389x10<-6> C15 -3.9837x10<-6> C17 9.5456x10<-8> C19 2.5646x10<-7> C21 8.4257x10<-8>

FFS2 &cir& C4 -4.8112x10<-2> C6 2.2437x10<-2> C8 1.2629x10<-2> C10 -1.4147x10<-3> C11 1.1201x10<-3> C13 -4.2802x10<-3> C15 -1.8265x10<-5>

FFS3 &cir& C4 -2.4894x10<-2> C6 1.7719x10<-3> C8 1.3030x10<-2> C10 8.7223x10<-3> C11 -2.5693x10<-3> C13 2.0937x10<-3> C15 -1.7955x10<-4>

FFS4 &cir& C4 1.4510x10<-2> C6 1.4974x10<-2> C8 6.3447x10<-5> C10 -3.3021x10<-5> C11 6.7340x10<-6> C13 1.3268x10<-5> C15 5.6476x10<-6>

FFS5 &cir& C4 -5.0177x10<-3> C6 4.2398x10<-3> C11 1.3297x10<-5> C13 1.7182x10<-5> C15 7.8122x10<-6>

FFS6 &cir& C4 6.6144x10<-2> C6 3.1372x10<-2> C11 5.4070x10<-4> C13 -2.1336x10<-4> C15 -4.3706x10<-4>

Displacement and tilt(1) X 0.00 Y 13.06 Z 30.44 alpha 4.48 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y -0.13 Z 38.51 alpha -29.74 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 17.85 Z 32.43 alpha 74.33 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 19.17 Z 33.07 alpha -102.30 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 44.66 Z 43.01 alpha -133.87 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 30.30 alpha -180.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 32.00 Z 48.57 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(8) X 0.00 Y 32.00 Z 53.57 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE> <tb><TABLE> Columns=6 <tb>Title: Example 21 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop)<SEP><SEP>(1)<SEP><SEP>% <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(3) <SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS2 &cir& <SEP><SEP>(4) <tb><SEP>6<SEP>FFS3 &cir& <SEP><SEP>(5) <SEP>1.5254<SEP>56.2 <tb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(6)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS5 &cir& (RE)<SEP><SEP>(7)<SEP>1.5254<SEP>56.2 <tb><SEP>9<SEP>FFS6 &cir& <SEP><SEP>(8) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(9)

ASS1 &cir& R -93.13 K 0.0000 A -7.3153x10<-6> B 1.0465x10<-8>

FFS1 &cir& C4 -1.2530x10<-2> C6 -1.0935x10<-2> C8 4.3572x10<-5> C10 5.6790x10<-5> C11 -4.6759x10<-6> C13 5.7024x10<-6> C15 -2.5865x10<-6> C17 5.1708x10<-8>C19 4.7739x10<-8> C21 4.8274x10<-8>

FFS2 &cir& C4 2.1276x10<-2> C6 -1.3001x10<-2> C8 1.2698x10<-2> C10 -4.0940x10<-3> C11 6.8259x10<-4> C13 -1.1193x10<-3> C15 -4.9525x10<-5>

FFS3 &cir& C4 -7.7818x10<-2> C6 -1.3978x10<-2> C8 8.2943x10<-3> C10 -3.6125x10<-3> C11 -2.1473x10<-3> C13 1.6422 x 10<-3> C15 2.1472x10<-4>

FFS4 &cir& C4 1.7708x10<-2> C6 9.8479x10<-3> C8 4.2747x10<-5> C10 1.4710x10<-5> C11 6.0476x10<-6> C13 9.5455x10<-6> C15 7.9647x10<-6>

FFS5 &cir& C4 -3.2083x10<-3> C6 -1.1682x10<-2> C8 -3.8379x10<-4> C10 -4.7983x10<-4> C11 3.2203x10<-5> C13 2.4146x10<-5> C15 1.5623x10<-5>

FFS6 &cir& C4 -1.2690x10<-2> C6 1.2046x10<-2>

Displacement and tilt(1) X 0.00 Y 0.00 Z 0.00 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y 11.12 Z 31.05 alpha 6.41 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y -0.11 Z 39.90 alpha -26.24 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 19.37 Z 34.98 alpha 52.37 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 19.70 Z 35.09 alpha -124.03 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 41.67 Z 44.93 alpha -137.82 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 36.67 Z 30.00 alpha -176.69 beta 0.00 gamma 0.00

Displacement and tilt(8) X 0.00 Y 32.00 Z 48.79 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(9) X 0.00 Y 32.00 Z 51.01 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE> <tb><TABLE> Columns=6 <tb>Title: Example 22 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop)<SEP><SEP>(1) <tb><SEP>2<SEP> INFINITY <SEP><SEP>(2)<SEP>1.4924<SEP>107.9 <tb><SEP>3<SEP>ASS1 &cir& <SEP><SEP>(3) <tb><SEP>4<SEP>ASS2 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS1 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>6<SEP>ASS2 &cir& (RE)<SEP><SEP>(4) <SEP>1.5254<SEP>56.2 <tb><SEP>7<SEP>FFS2 &cir& <SEP><SEP>(6) <tb><SEP>8<SEP>FFS3 &cir& <SEP><SEP>(7)<SEP>1.5254<SEP>56.2 <tb><SEP>9<SEP>FFS4 &cir& (RE)<SEP><SEP>(8)

<SEP>1.5254<SEP>56.2 <tb><SEP>10<SEP>FFS5 &cir& (RE)<SEP><SEP>(9)<SEP>1.5254<SEP>56.2 <tb><SEP>11<SEP>FFS6 &cir& <SEP><SEP>(10) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(11)

ASS1 &cir& R -31.17 K 0.0000 A -2.3392x10<-6> B 1.4417x10<-8>

ASS2 &cir& R -104.32 K 0.0000 A -1.1160x10<-5> B 1.3866x10<-8>

FFS1 &cir& C4 -1.1076x10<-2> C6 -9.7026x10<-3> C8 1.2453x10<-4> C10 8.6331x10<-5>

FFS2 &cir& C4 -2.6908x10<-2> C6 -2.2030x10<-2> C8 3.0544x10<-3> C10 -2.0443x10<-3>

FFS3 &cir& C4 -4.7273x10<-2> C6 -2.9318x10<-2> C8 4.8533x10<-4> C10 -2.1511x10<-3>

FFS4 &cir& C4 1.3337x10<-2> C6 7.7917x10<-3> C8 5.2903x10<-6> C10 3.2236x10<-5>

FFS5 &cir& C4 -7.4443x10<-3> C6 -1.1004x10<-2> C8 -3.4435 x 10<-4> C10 -2.7416x10<-4>

FFS6 &cir& C4 6.1792x10<-3> C6 7.4722x10<-3>

Displacement and tilt(1) X 0.00 Y 0.00 Z 0.00 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y 0.00 Z 25.00 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 0.00 Z 29.43 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 10.49 Z 30.94 alpha 6.19 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y -0.10 Z 40.19 alpha -24.76 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 18.51 Z 35.34 alpha 55.35 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 19.05 Z 35.60 alpha -111.46 beta 0.00 gamma 0.00

Displacement and tilt(8) X 0.00 Y 41.39 Z 45.63 alpha -142.01 beta 0.00 gamma 0.00

Displacement and tilt(9) X 0.00 Y 38.56 Z 29.81 alpha 177.05 beta 0.00 gamma 0.00

Displacement and tilt(10) X 0.00 Y 32.00 Z 49.26 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(11) X 0.00 Y 32.00 Z 51.37 alpha 0.00 13 beta 0.00 gamma 0.00 <tb></TABLE> <tb><TABLE> Columns=6 <tb>Title: Example 23 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1) <SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS2 &cir& <SEP><SEP>(3) <tb><SEP>6<SEP>FFS3 &cir& (RE)<SEP><SEP>(4) <tb><SEP>7<SEP>9.36<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>ASS2 &cir& <SEP><SEP>(6) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(7)

ASS1 &cir& R -112.57 K 0.0000 A 1.2804x10<-7> B 1.9023x10<-9>

ASS2 &cir& R 17.18 K 0.0000 A -1.1585x10<-4> B 4.5485x10<-6>

FFS1 &cir& C4 -1.0758x10<-2> C6 -1.0721x10<-2> C8 7.6154x10<-5> C10 -1.9106x10<-5> C11 4.9749x10<-6> C13 -5.3415x10<-6> C15 -2.8610x10<-6> C17 1.3623x10<-7> C19 2.9234x10<-8> C21 -5.0012x10<-9>

FFS2 &cir& C4 -4.2973x10<-2> C6 3.8451x10<-2> C8 3.6896x10<-3> C10 5.7252x10<-3> C11 1.4826x10<-4> C13 -1.1264x10<-3> C15 4.7888x10<-4>

FFS3 &cir& C4 2.0862x10<-2> C6 1.8162x10<-2> C8 1.4811x10<-4> C10 -2.1971x10<-5> C11 1.3347x10<-5> C13 2.3775x10<-5> C15 7.6542x10<-6>

Displacement and tilt(1) X 0.00 Y 12.30 Z 38.14 alpha -1.09 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y -0.33 Z 45.00 alpha -31.99 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 19.10 Z 42.18 alpha 78.03 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 39.78 Z 60.30 alpha -147.16 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 32.00 Z 40.06 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 37.55 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 32.00 Z 31.96 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE> <tb><TABLE> Columns=6 <tb>Title: Example 24 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1) <SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS2 &cir& <SEP><SEP>(3) <tb><SEP>6<SEP>FFS3 &cir& (RE)<SEP><SEP>(4) <tb><SEP>7<SEP>10.00<SEP><SEP>(5)<SEP>1.7400<SEP>45.0 <tb><SEP>8<SEP>-30.00<SEP><SEP>(6)<SEP>1.4875<SEP>70.2 <tb><SEP>9<SEP>20.00<SEP><SEP>(7) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(8)

ASS1 &cir& R -755.72 K 0.0000 A -3.0223x10<-6> B 3.6982x10<-9>

FFS1 &cir& C4 -1.3291x10<-2> C6 -9.1362x10<-3> C8 1.3010x10<-5> C10 -4.7998x10<-5> C11 3.8631x10<-8> C13 1.2388x10<-6> C15 -1.7367x10<-6> C17 4.1889x10<-7> C19 3.3450x10<-8> C21 1.5434x10<-8>

FFS2 &cir& C4 -4.9441x10<-2> C6 5.0481x10<-2> C8 -1.8555x10<-3> C10 1.1867x10<-3> C11 -1.0276x10<-3> C13 2.6209x10<-3> C15 1.5600x10<-4>

FFS3 &cir& C4 2.1838x10<-2> C6 2.0822x10<-2> C8 1.5599x10<-4> C10 2.2274x10<-5> C11 1.7287x10<-5> C13 3.1039x10<-5> C15 1.7347x10<-5>

Displacement and tilt(1) X 0.00 Y 15.24 Z 38.77 alpha 2.68 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y 0.01 Z 47.98 alpha -29.39 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 22.36 Z 42.21 alpha 83.11 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 38.88 Z 54.46 alpha -145.16 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 32.00 Z 34.24 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 33.17 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 32.00 Z 30.46 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(8) X 0.00 Y 32.00 Z 28.00 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE> <tb><TABLE> Columns=6 <tb>Title: Example 25 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object<SEP> INFINITY <SEP>-1000.00 <tb><SEP>plane <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1) <SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS2 &cir& <SEP><SEP>(3) <tb><SEP>6<SEP>FFS3 &cir& (RE)<SEP><SEP>(4) <tb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(5) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(6)

ASS1 &cir& R -142.30 K 0.0000 A -7.9459x10<-6> B 4.5193x10<-9>

FFS1 &cir& C4 -1.5782x10<-2> C6 -9.2595x10<-3> C8 8.4720x10<-5> C10 4.5249x10<-5> C11 1.0602x10<-5> C13 -8.7497x10<-6> C15 -4.4525 x 10<-6> C17 -5.8969x10<-8> C19 1.6760 x 10<-7> C21 1.2837x10<-7>

FFS2 &cir& C4 -4.8446x10<-2> C6 -8.3829x10<-3>

FFS3 &cir& C4 1.6543x10<-2> C6 9.5400x10<-3> C8 -1.0953x10<-4> C10 -1.8587x10<-5> C11 5.3062 x10<-6> C13 7.9992 x 10<-6> C15 5.7816x10<-6>

FFS4 &cir& C4 -4.2215x10<-3> C6 1.0692x10<-2> C8 -3.6896x10<-4> C10 -2.5259x10<-4> C11 5.9277x10<-6> C13 -1.3516x10<-5> C15 -7.8520x10<-6>

Displacement and tilt(1) X 0.00 Y 11.67 Z 32.96 alpha -1.41 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y -0.45 Z 40.56 alpha -30.45 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 18.56 Z 37.77 alpha 33.95 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 43.39 Z 48.16 alpha -135.03 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 36.28 Z 31.09 alpha 6.39 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 55.72 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE> <tb><TABLE> Columns=6 <tb>Title: Example 26 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>FFS1 &cir& <SEP><SEP>(1) <SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS2 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>FFS3 &cir& <SEP><SEP>(3) <tb><SEP>5<SEP>FFS4 &cir& <SEP><SEP>(4) <SEP>1.5254<SEP>56.2 <tb><SEP>6<SEP>FFS5 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>7<SEP>FFS6 &cir& <SEP><SEP>(6) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(7)

FFS1 &cir& C4 -6.2629x10<-3> C6 3.3796x10<-4> C8 3.9666x10<-4> C10 -1.2581x10<-4> C11 2.6158x10<-6> C13 3.2906x10<-5> C15 1.4501x10<-6>

FFS2 &cir& C4 -1.3276x10<-2> C6 -9.4693x10<-3> C8 -8.4725x10<-5> C10 -1.3499x10<-4> C11 -2.9102x10<-6> C13 -2.0112x10<-6> C15 -2.4589x10<-6> C17 -4.4244x10<-9> C19 -4.8328x10<-8> C21 -1.8143x10<-8>

FFS3 &cir& C4 -2.1469x10<-2> C6 -3.3694x10<-2> C8 -1.6179x10<-3> C10 -3.2678x10<-3> C11 -7.9899x10<-5> C13 -1.7505x10<-4> C15 -3.5647x10<-4>

FFS4 &cir& C4 -1.1648x10<-1> C6 -4.0332x10<-2> C8 -1.1348x10<-3> C10 1.9930x10<-3> C11 8.3579x10<-4> C13 8.0595x10<-4> C15 9.9925x10<-4>

FFS5 &cir& C4 1.9541x10<-2> C6 1.6255x10<-2> C8 -1.0516x10<-5> C10 -5.5991x10<-5> C11 4.5526x10<-6> C13 1.2743 x 10<-5> C15 3.8394x10-<6>

FFS6 &cir& C4 1.9172x10<-2> C6 3.2175x10<-2> C11 9.6401x10<-5> C13 -2.6951x10<-5> C15 -1.6440x10<-4>

Displacement and tilt(1) X 0.00 Y 0.00 Z 32.45 alpha -13.66 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y -1.36 Z 48.79 alpha -33.83 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 12.70 Z 41.59 alpha -50.46 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 19.62 Z 39.02 alpha -65.04 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 42.00 Z 30.00 alpha -44.81 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 45.53 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 32.00 Z 53.23 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE> <tb><TABLE> Columns=6 <tb>Title: Example 27 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object t plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1) <SEP>1.5254<SEP>56.2 2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>6<SEP>FFS2 &cir& <SEP><SEP>(3) <tb><SEP>7<SEP>FFS3 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS4 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>9<SEP>FFS5 &cir& <SEP><SEP>(6) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(7)

ASS1 &cir& R -109.37 K 0.0000 A 2.7422x10<-5> B -4.1869x10<-8>

FFS1 &cir& C4 -1.1126x10<-2> C6 -1.0227x10<-2> C8 -6.0588x10<-5> C10 -3.0318x10<-5> C11 7.9055x10<-6> C13 1.1105x10<-5> C15 1.0604x10<-6> C17 2.8597x10<-7> C19 1.5498x10<-7> C21 1.4283x10<-7>

FFS2 &cir& C4 3.6878x10<-2> C6 3.5702x10<-2> C8 -2.0106x10<-2> C10 -9.8201x10<-3> C11 2.1010x10<-3> C13 -1.9983x10<-3> C13 9.8827x10<-4>

FFS3 &cir& C4 -1.0254x10<-1> C6 -2.5575x10<-2> C8 -2.0239x10<-2> C10 -5.8721x10<-3> C11 1.0962x10<-3> C13 -3.3381x10<-3> C15 4.7815x10<-4>

FFS4 &cir& C4 2.3287x10<-2> C6 1.8127x10<-2> C8 -4.0703x10<-4> C10 -2.4676x10<-4> C11 1.9470x10<-5> C13 3.1178x10<-5> C15 -3.0929x10<-7>

FFS5 &cir& C4 -1.9980x10<-2> C6 -1.9644x10<-2> C11 1.8913x10<-4> C13 4.0095x10<-4> C15 5.1524x10<-4>

Displacement and tilt(1) X 0.00 Y 6.56 Z 32.12 alpha -2.57 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y -0.19 Z 38.74 alpha -23.54 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 20.79 Z 39.32 alpha -71.99 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 21.54 Z 38.60 alpha -84.73 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 36.81 Z 30.00 alpha -35.69 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 32.00 Z 44.11 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 32.00 Z 50.34 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE> <tb><TABLE> Columns=6 <tb>Title: Example 28 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe' S No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>FFS1 &cir& <SEP><SEP>(1) <SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS2 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>FFS3 &cir& (RE)<SEP><SEP>(3)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS4 &cir& <SEP><SEP>(4) <tb><SEP>6<SEP>FFS5 &cir& <SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>7<SEP>FFS6 &cir& (RE)<SEP><SEP>(6)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS7 &cir& (RE)<SEP><SEP>(7)<SEP>1.5254<SEP>56.2 <tb><SEP>9<SEP>FFS8 &cir& <SEP><SEP>(8) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(9)

FFS1 &cir& C4 -8.4040x10<-3> C6 -8.5948x10<-3>

FFS2 &cir& C4 -4.8109x10<-3> C6 -3.4151x10<-3> C8 7.6983x10<-6> C10 5.9643x10<-6>

FFS3 &cir& C4 8.5504x10<-4> C6 2.0899x10<-3> C8 3.9710x10<-6> C10 1.2427x10<-5>

FFS4 &cir& C4 -4.1338x10<-3> C6 4.6863x10<-3>

FFS5 &cir& C4 1.8948x10<-2> C6 7.8112x10<-3>

FFS6 &cir& C4 -2.9136x10<-3> C6 -2.6792x10<-3>

FFS7 &cir& C4 1.0066x10<-2> C6 1.0913x10<-2>

FFS8 &cir& C4 -2.2044x10<-2> C6 -1.6909x10<-2>

Displacement and tilt(1) X 0.00 Y 0.00 Z 30.00 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y 7.73 Z 66.05 alpha 18.69 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y -17.85 Z 38.62 alpha 46.96 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 20.71 Z 58.27 alpha 70.85 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 21.56 Z 58.79 alpha 72.18 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 41.10 Z 68.55 alpha 46.38 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 28.64 Z 46.33 alpha 17.45 beta 0.00 gamma 0.00

Displacement and tilt(8) X 0.00 Y 32.02 Z 71.98 alpha 0.00 beta 0.00 gamma 0.00

Displacement and tilt(9) X 0.00 Y 32.00 Z 76.97 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE> <tb><TABLE> Columns=6 <tb>Title: Example 29 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1)

<SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS2 &cir& <SEP><SEP>(3) <tb><SEP>6<SEP>FFS3 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2 <tb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS5 &cir& <SEP><SEP>(6) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(7)

ASS1 &cir& R 1285.39 K 0.0000 A 6.4599x10<-7> B -3.7861x10<-10>

FFS1 &cir& C4 -3.6795x10<-3> C6 -2.1319x10<-3> C8 -5.8405x10<-5> C10 -6. 5664x10<-5> C11 8. 2431x10<-7> C13 1.4603x10<-6> C15 1.4571x10<-6> C17 -5.6374x10<-8> C19 -3.7292x10<-8> C21 -4.3730x10<-8>

FFS2 &cir& C4 -3.1489x10<-4> C6 5.2538x10<-3> C8 1.2817x10<-3> C10 1.2156x10<-3> C11 5.1327x10<-6> C13 -1.0362x10<-5> C15 4.7618x10<-5>

F F S3 &cir& C4 -2.2969 x 10<-3> C6 -4. 7767x10<-4> C8 3.1569x10<-4> C10 1.9939x10<-4> C11 4.1969x10<-7> C13 1.3660x10<-5> C15 4.6817x10<-6>

FFS4 &cir& C4 2.2969x10<-3> C6 4.7767x10<-4> C8 -3.1569x10<-4> C10 -1.9939x10<-4> C11 -4.1969x10<-7> C13 -1.3660x10<-5> C15 -4.6817x10<-6>

FFS5 &cir& C4 2.5793x10<-2> C6-4.2457x10<-3> C11 -4.8745x10<-4> C13 -1.7443x10<-4> C15 -3.6717x10<-5>

Displacement and tilt(1) X 0.00 Y 10.19 Z 29.40 alpha 7.35 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y -3.29 Z 36.33 alpha -25.35 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 24.99 Z 36.53 alpha 82.49 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 18.12 Z 7.32 alpha -18.71 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y 18.12 Z -7.32 alpha 18.71 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 24.00 Z 0.00 alpha 90.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 0.00 Z 1.73 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE> <tb><TABLE> Columns=6 <tb>Title: Example 30 <tb> <tb>Head Col 1: Surface No. <tb>Head Col 2: Radius of curvature <tb>Head Col 3: Surface separation <tb>Head Col 4: Displacement and tilt <tb>Head Col 5: Refractive index <tb>Head Col 6: Abbe's No. <tb><SEP>Object plane<SEP> INFINITY <SEP>-1000.00 <tb><SEP>1<SEP> INFINITY (Stop) <tb><SEP>2<SEP>ASS1 &cir& <SEP><SEP>(1) <SEP>1.5254<SEP>56.2 <tb><SEP>3<SEP>FFS1 &cir& (RE)<SEP><SEP>(2)<SEP>1.5254<SEP>56.2 <tb><SEP>4<SEP>ASS1 &cir& (RE)<SEP><SEP>(1)<SEP>1.5254<SEP>56.2 <tb><SEP>5<SEP>FFS2 &cir& <SEP><SEP>(3) <tb><SEP>6<SEP>FFS3 &cir& <SEP><SEP>(4)<SEP>1.5254<SEP>56.2 <tb><SEP>7<SEP>FFS4 &cir& (RE)<SEP><SEP>(5)<SEP>1.5254<SEP>56.2 <tb><SEP>8<SEP>FFS5 &cir& <SEP><SEP>(6) <tb><SEP>Image plane<SEP> INFINITY <SEP><SEP>(7)

ASS1 &cir& R 368.58 K 0.0000 A 7.6841x10<-7> B -3.6756x10<-11>

FFS1 &cir& C4 -2.7696x10<-3> C6 -1.4546x10<-3> C8 -5.7608x10<-5> C10 -9.2334x10<-5> C11 5.8163x10<-7> C13 3.5074x10<-6> C15 2.2152x10<-6> C17 -1.8054 x 10<-7> C19 -1.1334x10<-7> C21 -1.0782x10<-7>

FFS2 &cir& C4 3.3609x10<-4> C6 8.4179x10<-2> C8 -3.1419x10<-5> C10 3.1128x10<-3> C11 3.4030x10<-5> C13 -1.1634x10<-4> C15 3.9570x10<-5>

FFS3 &cir& C4 -3.7622x10<-3> C6 -3.6532x10<-3> C8 1.5526x10<-4> C10 -5.4887x10<-6> C11 -7.4035x10<-6> C13 1.0763x10<-5> C15 -6.6288 x 10<-7>

FFS4 &cir& C4 3.7622x10<-3> C6 3.6532x10<-3> C6 -1.5526x10<-4> C10 5.4887x10<-6> C11 7.4035x10<-6> C13 -1.0763x10<-5> C15 6.6288x10<-7>

FFS5 &cir& C4 2.8169x10<-2> C6 4.5388x10<-4> C11 -4.5848x10<-4> C13 -8.7689 x10<-5> C15 -8.8053 x10<-6>

Displacement and tilt(1) X 0.00 Y 17.47 Z 30.07 alpha -1.32 beta 0.00 gamma 0.00

Displacement and tilt(2) X 0.00 Y 0.39 Z 38.40 alpha -28.76 beta 0.00 gamma 0.00

Displacement and tilt(3) X 0.00 Y 30.09 Z 31.35 alpha 36.81 beta 0.00 gamma 0.00

Displacement and tilt(4) X 0.00 Y 19.88 Z 6.67 alpha -15.86 beta 0.00 gamma 0.00

Displacement and tilt(5) X 0.00 Y. 19.88 Z -6.67 alpha 15.86 beta 0.00 gamma 0.00

Displacement and tilt(6) X 0.00 Y 29.00 Z 0.00 alpha 90.00 beta 0.00 gamma 0.00

Displacement and tilt(7) X 0.00 Y 0.00 Z 1.82 alpha 0.00 beta 0.00 gamma 0.00 <tb></TABLE>

[0154] Figs. 34, 35, 36, 37 and 38 are aberrational diagrams showing lateral aberrations in the above-described Examples 16, 20, 22, 29 and 30. In the diagrams showing lateral aberrations, the numerals in the parentheses denote (horizontal field angle, vertical field angle), and lateral aberrations at the field angles are shown.

[0155] It should be noted that the values of the conditions (4) and (6), which will be described later, in the above-described Examples 16 to 28 are as follows: <tb><TABLE> Columns=3 <tb> <tb>Head Col 1: <tb>Head Col 2: Condition (4) &thetas;1(<o>) <tb>Head Col 3: Condition (6) SIGMA D1(mm) <tb>Example 16<SEP>22.5<SEP>119.4 <tb>Example 17<SEP>41.0<SEP>57.7 <tb>Example 18<SEP>37.2<SEP>62.5 <tb>Example 19<SEP>22.0<SEP>33.4 <tb>Example 20<SEP>26.1<SEP>99.4 <tb>Example 21<SEP>18.8<SEP>92.7 <tb>Example 22<SEP>25.6<SEP>95.7 <tb>Example 23<SEP>41.2<SEP>58.3 <tb>Example 24<SEP>36.6<SEP>50.1 <tb>Example 25<SEP>22.7<SEP>70.4 <tb>Example 26<SEP>20.4<SEP>78.5 <tb>Example 27<SEP>43.8<SEP>56.2 <tb>Example 28<SEP>31.2<SEP>117.5 <tb></TABLE>

[0156] Next, the values concerning the conditions (1) to (3) in the above-described Examples 29 and 30 are as follows: <tb><TABLE> Columns=4 <tb> <tb>Head Col 1: <tb>Head Col 2: <tb>Head Col 3: Example 29 <tb>Head Col 4: Example 30 <tb>Condition (1)<SEP> alpha <SEP>43 DEG </=a</=54 DEG <SEP>43 DEG </=a</=58 DEG <tb>Condition (2)<SEP> beta <SEP>19 DEG <SEP>18 DEG <tb>Condition (3) <SEP>D<SEP>27.5 mm<SEP>31 mm <tb><SEP>L<SEP>72 mm<SEP>72 mm <tb><SEP>D/L<SEP>0.38<SEP>0.43 <tb></TABLE>

[0157] It should be noted that the free-form surfaces in the above-described Examples 16 to 30 may be replaced with spherical surfaces including plane surfaces, aspherical surfaces, anamorphic surfaces, or anamorphic aspherical surfaces.

[0158] Regarding the optical system of the image display apparatus according to the present invention as stated above, when a ray passing through the center of the image displayed by the image display device 3 and further passing through the center of a right-hand pupil 4R formed by the ocular prism 2R for the right eye is defined as a right-hand optical axis, and a ray passing through the center of the image displayed by the image display device 3 and further passing through the center of a left-hand pupil 4L formed by the ocular prism 2L for the left eye is defined as a left-hand optical axis, it is desirable to satisfy the following condition: "(4)" 10 DEG <&thetas;1<60 DEG where &thetas;1 is the absolute value of the angle formed between each of the right-hand optical axis and the left-hand optical axis, which enter the ocular prism 2R for the right eye and the ocular prism 2L for the left eye from the optical path distributing mirror 1 or the optical path distributing prism 10, and the display surface of the image display device 3.

[0159] The condition (4) limits the angle formed between the axial principal ray entering the ocular prisms 2R and 2L from the optical path distributing means, which comprises the optical path distributing mirror 1 or the optical path distributing prism 10, and the image display device 3.

[0160] If &thetas;1 is not larger than the lower limit of the above condition (4), i.e. 10 DEG , the axial principal ray entering the ocular prisms from the optical path distributing means undesirably forms an optical path approximately parallel to the image display device. Consequently, it becomes difficult to ensure the left and right optical paths. Accordingly, it becomes necessary to use a half-mirror in order to distribute the optical path from a single image display device, e.g. an LCD, to the left and right ocular prisms. The use of a half-mirror results in an unfavorably dark image. If &thetas;1 is not smaller than the upper limit of the condition (4), i.e. 60 DEG , it is necessary to tilt each ocular prism to a considerable extent or to increase the size of the prism itself. Consequently, it becomes impossible to attain a compact and lightweight optical system.

[0161] It is more desirable for the above condition to be the following condition (5): "(5)" 15 DEG <&thetas;1<50 DEG

[0162] If the angle &thetas;1 is within the range defined by the above condition, it is possible to attain a further reduction in size of the apparatus while ensuring the left and right optical paths.

[0163] Further, when the distance from the image display device 3 to each of the entrance surface 21R of the ocular prism 2R for the right eye and the entrance surface 21L of the ocular prism 2L for the left eye along the optical axis is denoted by SIGMA D1, it is desirable to satisfy the following condition: "(6)" 20 mm< SIGMA D1<150 mm

[0164] The above condition (6) is a condition for attaining a reduction in size of the apparatus, which defines the optical path length of the axial principal ray from the image display device 3 to each of the ocular prisms 2R and 2L.

[0165] If SIGMA D1 is not larger than the lower limit of the above condition (6), i.e. 20 mm, the power of each surface of the optical path distributing means becomes extremely strong. Consequently, it becomes impossible to favorably correct decentration aberrations, particularly decentration comatic aberration. In addition, the angle between the image display device 3 and the rays (principal ray tilt angle) becomes extremely large, which is unfavorable. If SIGMA D1 is not smaller than the upper limit of the condition (6), i.e. 150 mm, the optical path distributing means becomes large in size and projects to a considerable extent in comparison to the ocular prisms, unfavorably.

[0166] It is more desirable for the above condition to be the following condition (7): "(7)" 30 mm< SIGMA D1<130 mm

[0167] If SIGMA D1 is within the range defined by the above condition, it is possible to attain a further reduction in size of the apparatus while maintaining the favorable performance.

[0168] It is even more desirable for the above condition to be the following condition (8): "(8)" 45 mm<ED1<120 mm

[0169] If SIGMA D1 is within the range defined by the above condition, it is possible to attain a further reduction in size of the apparatus while maintaining the favorable performance.

[0170] In the above-described optical system of the image display apparatus according to the present invention, it is possible to perform see-through observation of the outside world by bonding, as shown for example in Fig. 39, compensating prisms 16L and 16R to the reflecting surfaces 23L and 23R (in the case of Fig. 26, the reflecting surfaces 22L and 22R; in the case of Fig. 27, 22L, 22R, 24R and 24R; and in the case of Fig. 28, 23L and 23R) of the decentered prism members 2L and 2R for the left and right eyes on the outside-world sides thereof (on the sides thereof remote from the observer's face) or placing the compensating prisms 16L and 16R at a slight distance from the reflecting surfaces 23L and 23R as half-mirror surfaces for compensating for bending of the optical paths and further forming the outside world-side surfaces 17L and 17R of the compensating prisms 16L and 16R so that the surfaces 17L and 17R have approximately the same configurations as those of the observer's face-side transmitting surfaces 24L and 24R, respectively (in the case of Fig. 26, the transmitting surfaces 23L and 23R; in the case of Fig. 27, 25L and 25R; and in the case of Fig. 28, 24L and 24R) of the decentered prism members 2L and 2R for the left and right eyes, thereby allowing light from the outside world to pass approximately in straight lines. In this case, superimposing function or see-through function can be added by placing means for changing the transmittance of light from the outside world, e.g. a liquid crystal shutter, on the outside world side of the compensating prisms 16L and 16R.

[0171] In the present invention, a transmission type or reflection type LCD (liquid crystal display device) can be used as the image display device 3, as stated above. However, the use of a self-emission type panel makes it possible to simplify the structure and hence possible to construct a lightweight image display apparatus. The use of an LCD as the image display device 3 involves the problem that an illuminating light source, e.g. a backlight, is needed, and the problem that an LCD invariably needs a polarizer, and only a half of illuminating light can be used for display.

[0172] Therefore, it is desirable to use a self-emission type panel (display). Examples of self-emission panels include OLEDs (Organic Light Emitting Diodes), LEDs (Light Emitting Diodes), and an EL (Electroluminescence) panel having a structure such as that illustrated in Fig. 40.

[0173] Fig. 40 shows the structure of an organic EL comprising three layers. An organic EL layer comprising three layers, i.e. a hole injection layer, an organic EL layer, and an electron injection layer, is sandwiched between pixel electrodes provided on an Si substrate and having a switching element placed for each pixel and an ITO film provided on the lower surface of a glass substrate as a common electrode. When a voltage is applied between the ITO film and the pixel electrodes by the action of the switching elements, holes are injected into the organic EL layer from the hole injection layer and electrons are injected into the organic EL layer from the electron injection layer. The holes and the electrons recombine in the organic EL layer, causing the portions of the organic EL layer corresponding to the pixels to emit light. Thus, the desired image is displayed.

[0174] The advantage of the use of such a light-emission type display in the image display apparatus lies in its excellent viewing angle characteristics. In particular, in a head-mounted image display apparatus (HMD) designed for observation with two eyes, the pupils of the optical systems and the observer's pupils may be displaced with respect to each other owing to a difference in interpupillary distance among observers or displacement of the HMD body. In order to prevent the image for observation from darkening even when the observer's pupils are displaced, it is important to make the pupils of the optical systems free from aberrations over a wide range. Even if the optical systems are designed so that the pupils are widened, when the pupils are displaced, the observer is placed under conditions where he or she views the image display device obliquely through the ocular optical systems. In general, image display devices using LCD are inferior in viewing angle characteristics when viewed obliquely. That is, it is possible to view only an image for observation that is reduced in contrast or undesirably tone-reversed. Accordingly, the brightness and contrast of the image field undesirably vary according to the fitting position of the HMD, and it is difficult to view the image with stable image quality. With a light-emission type image display device, such problems are unlikely to occur, and it is therefore favorable for use as an image display device for an HMD.

[0175] Incidentally, it is possible to form a stationary or portable image display apparatus by preparing and supporting one set of image display apparatus according to the present invention arranged as stated above. Fig. 41 shows the image display apparatus. In Fig. 41, reference numeral 31 denotes a display apparatus body unit, which is fixed by a support member through the observer's head so that the display apparatus body unit 31 is held in front of both the observer's eyes. The support member has a pair of front frames 32 (left and right) each joined at one end thereof to the display apparatus body unit 31. The left and right front frames 32 extend from the observer's temples to the upper portions of his/her ears, respectively. A pair of rear frames 33 (left and right) are joined to the other ends of the front frames 32, respectively, and extend over the side portions of the observer's head. Alternatively, the support member further has a top frame 34 joined at both ends thereof to the other ends of the left and right rear frames 33, respectively, so that the top frame 34 supports the top of the observer's head.

[0176] A rear plate 35 is joined to one front frame 32 near the joint to the rear frame 33. The rear plate 35 is formed from an elastic member, e.g. a metal leaf spring. A rear cover 36, which constitutes a part of the support member, is joined to the rear plate 35 so that the rear cover 36 can support the apparatus at a position behind the observer's ear in a region extending from the back part of the head to the base of the neck. A speaker 39 is mounted inside the rear plate 35 or the rear cover 36 at a position corresponding to the observer's ear.

[0177] A cable 41 for transmitting external image and sound signals is led out from the display apparatus body unit 31. The cable 41 extends through the top frame 34, the rear frames 33, the front frames 32 and the rear plate 35 and projects to the outside from the rear end of the rear plate 35 or the rear cover 36. The cable 41 is connected to a video-replaying unit 40. It should be noted that reference numeral 40a in the figure denotes a switch and volume control part of the video-replaying unit 40.

[0178] The cable 41 may have a jack and plug arrangement attached to the distal end thereof so that the cable 41 can be connected to an existing video deck or the like. The cable 41 may also be connected to a TV signal-receiving tuner so as to enable the user to enjoy watching TV. Alternatively, the cable 41 may be connected to a computer to receive computer graphic images or message images or the like from the computer. To eliminate the bothersome cord, the apparatus may be arranged to receive external radio signals through an antenna connected thereto.

INDUSTRIAL APPLICABILITY

[0179] As will be clear from the foregoing description, it is possible according to the present invention to provide an image display apparatus, e.g. a head-mounted image display apparatus, in which an image from a single image display device is led to two eyes without using a half-mirror, thereby allowing observation of a bright image, and in which an optical path distributing mirror or an optical path distributing prism placed at the middle between the two eyes facilitates the correction of various aberrations. In addition, it is possible to obtain an illuminating arrangement which is the most suitable for observation of a single panel with two eyes and which can be used without the need to switch the display image for the left and right.

IMAGE DISPLAY

Claims of corresponding document: EP 1186933 (A1)

1. An image display apparatus comprising an image display device for displaying an image to be observed by an observer, an optical path distributing mirror for distributing said image to an optical path for a right eye and an optical path for a left eye, an ocular prism for the right eye that is placed on a right-hand side of said optical path distributing mirror, and an. ocular prism for the left eye that is placed on a left-hand side of said optical path distributing mirror, said optical path distributing mirror having a mirror surface placed to face said image display device to reflect a display light beam emanating from said image display device so as to distribute the display light beam to said ocular prism for the right eye and said prism for the left eye, said mirror surface having a rotationally asymmetric curved surface configuration that corrects decentration aberrations, said ocular prism for the right eye having a first surface through which the light beam of the optical path for the right eye reflected by said optical path distributing mirror enters the prism, a second surface which reflects the light beam of the optical path for the right eye within the prism, and a third surface through which the light beam of the optical path for the right eye exits from the prism, said ocular prism for the left eye having a first surface through which the light beam of the optical path for the left eye reflected by said optical path distributing mirror enters the prism, a second surface which reflects the light beam of the optical path for the left eye within the prism, and a third surface through which the light beam of the optical path for the left eye exits from the prism, wherein at least the second surface of said ocular prism for the right eye, which is a reflecting surface, and the second surface of said ocular prism for the left eye, which is a reflecting surface, have a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

2. An image display apparatus according to claim 1, wherein the rotationally asymmetric curved surface configuration of said optical path distributing mirror is a free-form surface having only one plane of symmetry.

3. An image display apparatus according to claim 2, wherein the free-form surface of said optical path distributing mirror has said only one plane of symmetry in a plane (YZ-plane) connecting a center of the image displayed by said image display device and a center of a right-hand pupil formed by said ocular prism for the right eye and further a center of a left-hand pupil formed by said ocular prism for the left eye.

4. An image display apparatus according to any one of claims 1 to 3, wherein said image display device is placed between said optical path distributing mirror and said observer in a longitudinal direction (Z-direction) and between said ocular prism for the right eye and said ocular prism for the left eye in a lateral direction (Y-direction).

5. An image display apparatus according to any one of claims 1 to 3, wherein a negative lens that gives a negative power to a light beam is placed between said image display device and said optical path distributing mirror.

6. An image display apparatus according to any one of claims 1 to 3, wherein said ocular prism for the right eye is arranged so that a light beam exiting from said optical path distributing mirror and entering the prism through said first surface is made incident on said third surface at an angle larger than a total reflection critical angle so as to be reflected toward said second surface within the prism by total reflection, and the light beam reflected from said second surface is made incident on said third surface at an angle smaller than the total reflection critical angle so as to pass through said third surface to exit from the prism, and wherein said ocular prism for the left eye is arranged so that a light beam exiting from said optical path distributing mirror and entering the prism through said first surface is made incident on said third surface at an angle larger than a total reflection critical angle so as to be reflected toward said second surface within the prism by total reflection, and the light beam reflected from said second surface is made incident on said third surface at an angle smaller than the total reflection critical angle so as to pass through said third surface to exit from the prism.

7. An image display apparatus according to any one of claims 1 to 3, wherein said first surface of said ocular prism for the right eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations, and wherein said first surface of said ocular prism for the left eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

8. An image display apparatus according to claim 7, wherein the rotationally asymmetric curved surface configuration of said first surface of said ocular prism for the right eye is a free-form surface having only one plane of symmetry, and wherein the rotationally asymmetric curved surface configuration of said first surface of said ocular prism for the left eye is a free-form surface having only one plane of symmetry.

9. An image display apparatus according to claim 8, wherein when a light ray passing through a center of the image displayed by said image display device and further passing through a center of a right-hand pupil formed by said ocular prism for the right eye is defined as an optical axis, the free-form surface of said first surface of said ocular prism for the right eye has said only one plane of symmetry in a plane (YZ-plane) containing the optical axis in a folded optical path within the prism, and wherein when a light ray passing through the center of the image displayed by said image display device and further passing through a center of a right-hand pupil formed by said ocular prism for the left eye is defined as an optical axis, the free-form surface of said first surface of said ocular prism for the left eye has said only one plane of symmetry in a plane (YZ-plane) containing the optical axis in a folded optical path within the prism.

10. An image display apparatus according to any one of claims 1 to 3, wherein said third surface of said ocular prism for the right eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations, and wherein said third surface of said ocular prism for the left eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

11. An image display apparatus according to claim 10, wherein the rotationally asymmetric curved surface configuration of said third surface of said ocular prism for the right eye is a free-form surface having only one plane of symmetry, and wherein the rotationally asymmetric curved surface configuration of said third surface of said ocular prism for the left eye is a free-form surface having only one plane of symmetry.

12. An image display apparatus according to claim 11, wherein when a light ray passing through a center of the image displayed by said image display device and further passing through a center of a right-hand pupil formed by said ocular prism for the right eye is defined as an optical axis, the free-form surface of said third surface of said ocular prism for the right eye has said only one plane of symmetry in a plane (YZ-plane) containing the optical axis in a folded optical path within the prism, and wherein when a light ray passing

through the center of the image displayed by said image display device and further passing through a center of a right-hand pupil formed by said ocular prism for the left eye is defined as an optical axis, the free-form surface of said third surface of said ocular prism for the left eye has said only one plane of symmetry in a plane (YZ-plane) containing the optical axis in a folded optical path within the prism.

13. An image display apparatus according to any one of claims 1 to 3, wherein said third surface of said ocular prism for the right eye is a rotationally symmetric aspherical surface, and wherein said third surface of said ocular prism for the left eye is a rotationally symmetric aspherical surface.

14. An image display apparatus comprising an image display device for displaying an image to be observed by an observer, an optical path distributing prism for distributing said image to an optical path for a right eye and an optical path for a left eye, an ocular prism for the right eye that is placed on a right-hand side of said optical path distributing prism, and an ocular prism for the left eye that is placed on a left-hand side of said optical path distributing prism, said optical path distributing prism having at least a first surface placed to face said image display device so that a display light beam emanating from said image display device enters the prism through the first surface, a second-first surface which reflects said optical path for the right eye entering through said first surface, a second-second surface which reflects said optical path for the left eye entering through said first surface, a third-first surface through which the light beam of said optical path for the right eye exits from the prism, and a third-second surface through which the light beam of said optical path for the left eye exits from the prism, said optical path distributing prism being arranged so that at least said second-first surface and said second-second surface have a curved surface configuration that gives a power to a light beam to form a relay image for the right eye from the image displayed by said image display device in said optical path for the right eye and to form a relay image for the left eye from the image displayed by said image display device in said optical path for the left eye, and said second-first surface and said second-second surface have a same surface configuration, said ocular prism for the right eye having a first surface through which the light beam of the optical path for the right eye exiting from said third-first surface of said optical path distributing prism enters the prism, a second surface which reflects the light beam of the optical path for the right eye within the prism, and a third surface through which the light beam of the optical path for the right eye exits from the prism, said ocular prism for the left eye having a first surface through which the light beam of the optical path for the left eye exiting from said third-second surface of said optical path distributing prism enters the prism, a second surface which reflects the light beam of the optical path for the left eye within the prism, and a third surface through which the light beam of the optical path for the left eye exits from the prism, wherein at least said second surface of said ocular prism for the right eye, which is a reflecting surface, and said second surface of said ocular prism for the left eye, which is a reflecting surface, have a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

15. An image display apparatus according to claim 14, wherein the third-first surface and third-second surface of said optical path distributing prism are curved surfaces of a same configuration.

16. An image display apparatus according to claim 14 or 15, wherein the first surface, second-first surface, second-second surface, third-first surface and third-second surface of said optical path distributing prism form optical surfaces of the prism as surfaces which are independent of each other, and wherein the second-first surface, second-second surface, third-first surface and third-second surface of said optical path distributing prism have a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

17. An image display apparatus according to claim 15, wherein the curved surface configuration of the third-first surface and third-second surface of said optical path distributing prism is a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

18. An image display apparatus according to claim 15, wherein the curved surface configuration of each of the second-first surface, second-second surface, third-first surface and third-second surface of said optical path distributing prism is a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

19. An image display apparatus according to any one of claims 15 to 18, wherein said image display device and said optical path distributing prism are placed to face each other, said optical path distributing prism being arranged so that, according as a distance from said image display device increases in a longitudinal direction (Z-direction), said first surface is located first, and then said second-first surface and said second-second surface are disposed at left and right positions facing each other across a medium, and then said third-first surface and said third-second surface are located, wherein said third-first surface is disposed at a position facing the first surface of said ocular prism for the right eye across an air spacing, and said third-second surface is disposed at a position facing the first surface of said ocular prism for the left eye across an air spacing.

20. An image display apparatus according to any one of claims 15 to 18, wherein said image display device and said optical path distributing prism are placed to face each other, said optical path distributing prism being arranged so that, according as a distance from said image display device increases in a longitudinal direction (Z-direction), said first surface is located first, and then said third-first surface and said third-second surface are disposed at right and left positions facing each other across a medium, and then said second-first surface and said second-second surface are located, wherein said third-first surface is disposed at a position facing the first surface of said ocular prism for the right eye across an air spacing, and said third-second surface is disposed at a position facing the first surface of said ocular prism for the left eye across an air spacing.

21. An image display apparatus according to claim 14, wherein a single surface is used as both said second-first surface and third-second surface of said optical path distributing prism, and a single surface is used as both said second-second surface and third-first surface of said optical path distributing prism, wherein said optical path for the right eye is made incident on the surface used as both said second-first surface and said third-second surface at an angle larger than a total reflection critical angle to reflect the light beam of the optical path for the right eye within the prism by total reflection, and said optical path for the right eye is made incident on the surface used as both said second-second surface and said third-first surface at an angle smaller than the total reflection critical angle to allow the light beam of the optical path for the right eye to exit from the prism, wherein said optical path for the left eye is made incident on the surface used as both the second-second surface and the third-first surface at an angle larger than the total reflection critical angle to reflect the light beam of the optical path for the left eye within the prism by total reflection, and said optical path for the left eye is made incident on the surface used as both the second-first surface and the third-second surface at an angle smaller than the total reflection critical angle to allow the light beam of the optical path for the left eye to exit from the prism, and wherein the surface used as both said second-first surface and third-second surface has a rotationally asymmetric curved surface configuration that corrects decentration aberrations, and the surface used as both said second-second surface and third-first surface has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

22. An image display apparatus according to any one of claims 14 to 18, wherein said optical path distributing prism has a fourth surface with a curved surface configuration that reflects light beams of right and left images entering through the first surface toward the second-first surface and the second-second surface, respectively, wherein the first surface, second-first surface, second-second surface, third-first surface, third-second surface and fourth surface of said optical path distributing prism form optical surfaces of the prism as surfaces which are independent of each other.

23. An image display apparatus according to claim 22, wherein the curved surface configuration of the fourth surface of said optical path distributing prism is a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

24. An image display apparatus according to claim 23, wherein said image display device and said optical path distributing prism are placed to face each other, said optical path distributing prism being arranged so that, according as a distance from said image display device increases in a longitudinal direction (Z-direction), said first surface is located first, and then said second-first surface and said second-second surface are disposed at left and right positions facing each other across a medium, and then said third-first surface and said thirdsecond surface are located, said fourth surface being disposed at a position facing said first surface across the medium, wherein said third-first surface is disposed at a position facing the first surface of said ocular prism for the right eye across an air spacing, and said third-second surface is disposed at a position facing the first surface of said ocular prism for the left eye across an air spacing.

25. An image display apparatus according to any one of claims 14 to 18, wherein said optical path distributing prism has a fourth-first surface which reflects the optical path for the right eye entering through the first surface toward the second-first surface, and a fourth-second surface which reflects the optical path for the left eye entering through the first surface toward the second-second surface, wherein the first surface, second-first surface, second-second surface, third-first surface, third-second surface, fourth-first surface and fourth-second surface of said optical path distributing prism form optical surfaces of the prism as surfaces which are independent of each other.

26. An image display apparatus according to claim 25, wherein the fourth-first surface and fourth-second surface of said optical path distributing prism are curved surfaces of a same configuration.

27. An image display apparatus according to claim 26, wherein the curved surface configuration of the fourth-first surface and fourth-second surface of said optical path distributing prism is a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

28. An image display apparatus according to claim 27, wherein said image display device and said optical path distributing prism are placed to face each other, said optical path distributing prism being arranged so that, according as a distance from said image display device increases in a longitudinal direction (Z-direction), said first surface is located first, and then said second-first surface and said second-second surface are disposed at left and right positions, respectively, facing each other across a medium, and then said third-second surface and said third-first surface are disposed at left and right positions, respectively, facing each other across the medium, and then the fourth-first surface and the fourth-second surface are disposed adjacently to each other at respective positions facing said first surface across the medium.

29. An image display apparatus according to any one of claims 14 to 28, wherein said first surface of said optical path distributing prism has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

30. An image display apparatus according to any one of claims 14 to 18, wherein the rotationally asymmetric curved surface of said optical path distributing prism is a free-form surface having only one plane of symmetry.

31. An image display apparatus according to claim 30, wherein the free-form surface of said optical path distributing prism has said only one plane of symmetry in a plane (YZ-plane) connecting a center of the image displayed by said image display device and a center of a pupil.

32. An image display apparatus according to any one of claims 14 to 18, wherein said ocular prism for the right eye is arranged so that a light beam exiting from said optical path distributing prism and entering the prism through said first surface is made incident on said third surface at an angle larger than a total reflection critical angle so as to be reflected toward said second surface within the prism by total reflection, and the light beam reflected from said second surface is made incident on said third surface at an angle smaller than the total reflection critical angle so as to pass through said third surface to exit from the prism, and wherein said ocular prism for the left eye is arranged so that a light beam exiting from said optical path distributing prism and entering the prism through said first surface is made incident on said third surface at an angle larger than a total reflection critical angle so as to be reflected toward said second surface within the prism by total reflection, and the light beam reflected from said second surface is made incident on said third surface at an angle smaller than the total reflection critical angle so as to pass through said third surface to exit from the prism.

33. An image display apparatus according to any one of claims 14 to 18, wherein said ocular prism for the right eye is arranged so that a light beam exiting from said optical path distributing prism and entering the prism through said first surface is reflected by said second surface, and the light beam reflected from said second surface passes through said third surface to exit from the prism, and wherein said ocular prism for the left eye is arranged so that a light beam exiting from said optical path distributing prism and entering the prism through said first surface is reflected by said second surface, and the light beam reflected from said second surface passes through said third surface to exit from the prism.

34. An image display apparatus according to any one of claims 14 to 18, wherein said ocular prism for the right eye has alpha fourth surface which reflects a light beam within the prism, said ocular prism for the right eye being arranged so that a light beam exiting from said optical path distributing prism and entering the prism through said first surface is reflected by said fourth surface, and the light beam reflected from said fourth surface is made incident on said third surface at an angle larger than a total reflection critical angle so as to be reflected toward said second surface within the prism by total reflection, and further the light beam reflected from said second surface is made incident on said third surface at an angle smaller than the total reflection critical angle so as to pass through said third surface to exit from the prism, and wherein said ocular prism for the left eye has a fourth surface which reflects a light beam within the prism, said ocular prism for the left eye being arranged so that a light beam exiting from said optical path distributing prism and entering the prism through said first surface is reflected by said fourth surface, and the light beam reflected from said fourth surface is made incident on said third surface at an angle larger than a total reflection critical angle so as to be reflected toward said second surface within the prism by total reflection, and further the light beam reflected from said second surface is made incident on said third surface at an angle smaller than the total reflection critical angle so as to pass through said third surface to exit from the

prism.

35. An image display apparatus according to claim 34, wherein the fourth surface of said ocular prism for the right eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations, and wherein the fourth surface of said ocular prism for the left eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

36. An image display apparatus according to any one of claims 14 to 18, wherein the first surface of said ocular prism for the right eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations, and wherein the first surface of said ocular prism for the left eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

37. An image display apparatus according to any one of claims 14 to 18, wherein the second surface of said ocular prism for the right eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations, and wherein the second surface of said ocular prism for the left eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

38. An image display apparatus according to any one of claims 14 to 18, wherein the third surface of said ocular prism for the right eye is a rotationally symmetric aspherical surface, and wherein said third surface of said ocular prism for the left eye is a rotationally symmetric aspherical surface.

39. An image display apparatus according to any one of claims 14 to 18, wherein the third surface of said ocular prism for the right eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations, and wherein the third surface of said ocular prism for the left eye has a rotationally asymmetric curved surface configuration that corrects decentration aberrations.

40. An image display apparatus according to any one of claims 14 to 18, wherein said optical path distributing prism has a positive power as a whole so that said relay image for the right eye is formed at a position closer to the right eye of the observer than said third-first surface on the optical path and said relay image for the left eye is formed at a position closer to the left eye of the observer than said third-second surface on the optical path.

41. An image display apparatus according to claim 40, wherein said optical path distributing prism forms said relay image for the right eye at a position between said third-first surface and the first surface of said ocular prism for the right eye and further forms said relay image for the left eye at a position between said third-second surface and the first surface of said ocular prism for the left eye.

42. An image display apparatus according to any one of claims 14 to 18, wherein an angle alpha of reflection of display light of the optical path for the right eye from the second-first surface of said optical path distributing prism and an angle alpha of reflection of display light of the optical path for the left eye from the second-second surface of said optical path distributing prism satisfy the following condition: "(1)" 33 DEG </= alpha </=70 DEG

43. An image display apparatus according to any one of'claims 14 to 18, wherein an angle beta formed between a plane passing through a center of a line segment connecting a center of an exit pupil for the right eye and a center of an exit pupil for the left eye at right angles to the line segment and a tangent plane to the second-first surface of said optical path distributing prism at a point where the optical axis of the optical path for the right eye is incident on said second-first surface and an angle beta formed between the plane passing through the center of the line segment connecting the center of the exit pupil for the right eye and the center of the exit pupil for the left eye at right angles to the line segment and a tangent plane to the second-second surface of said optical path distributing prism at a point where the optical axis of the optical path for the left eye is incident on said second-second surface satisfy the following condition: "(2)" 13 DEG </= beta </=24 DEG

44. An image display apparatus according to any one of claims 14 to 18, wherein, in backward ray tracing from a pupil side, a distance between an intersection of a ray passing through a center of an exit pupil for the right eye at a maximum field angle on a right-hand side and the third surface of said ocular prism for the right eye and an intersection of a ray passing through a center of an exit pupil for the left eye at a maximum field angle on a left-hand side and the third surface of said ocular prism for the left eye is defined as a width L, and a distance between a point closest to the left and right exit pupils among points at which bundles of rays passing through the centers of the left and right exit pupils within an overall field angle pass through or are reflected by the third surface of said ocular prism for the right eye or the third surface of said ocular prism for the left eye and a display surface of said image display device in a direction perpendicular to the display surface is defined as a depth D, wherein a ratio of the depth D to the width L, i.e. D/L, satisfies the following condition: "(3)" 0.3</=D/L</=0.5

45. An image display apparatus according to any one of claims 14 to 18, wherein the second surface of said ocular prism for the right eye is a semitransparent reflecting surface, and a see-through prism for the right eye is placed outside said second surface, and wherein the second surface of said ocular prism for the left eye is a semitransparent reflecting surface, and a see-through prism for the left eye is placed outside said second surface.

46. An image display apparatus comprising an image display device for displaying an image to be observed by an observer, an optical path distributing prism for distributing said image to an optical path for a right eye and an optical path for a left eye, an ocular prism for the right eye that is placed on a right-hand side of said optical path distributing prism, and an ocular prism for the left eye that is placed on a left-hand side of said optical path distributing prism, said optical path distributing prism having at least a first surface placed to face said image display device so that a display light beam emanating from said image display device enters the prism through the first surface, a second-first surface which reflects said optical path for the right eye entering through said first surface, a second-second surface which reflects said optical path for the left eye entering through said first surface, a third-first surface through which the light beam of said optical path for the right eye exits from the prism, and a third-second surface through which the light beam of said optical path for the left eye exits from the prism, said optical path distributing prism being arranged so that at least said second-first surface, said second-second surface, said third-first surface and said third-second surface have a curved surface configuration that gives a power to a light beam, and said second-first surface and said second-second surface have a same surface configuration and said third-first surface and said third-second surface have a same surface configuration, said image display device being a reflection type image display device that displays an image by reflecting a light beam from a light source, wherein both said second-first surface and secondsecond surface of said optical path distributing prism are either semitransparent reflecting surfaces or partially-transmitting and partially-reflecting surfaces, and wherein an illuminating light source for forming the optical path for the left eye is disposed at a position on a side of said second-first surface remote from a prism medium, and an illuminating light source for forming the optical path for the right eye is disposed at a position on a side of said second-second surface remote from the prism medium.

47. An image display apparatus comprising an image display device for displaying an image to be observed by an observer, an optical path distributing prism for distributing said image to an optical path for a right eye and an optical path for a left eye, an ocular prism for the right eye that is placed on a right-hand side of said optical path distributing prism, and an ocular prism for the left eye that is placed on a left-hand side of said optical path distributing prism, said optical path distributing prism having at least a first surface placed to face said image display device so that a display light beam emanating from said image display device enters the prism through the first surface, a fourth surface placed to face said first surface across a medium so as to reflect light beams of right and left images entering through said first surface in different directions, thereby distributing the light beams to the optical path for the right eye and the optical path for the left eye, a second-first surface which reflects said optical path for the right eye reflected from said fourth surface, a second-second surface which reflects said optical path for the left eye reflected from said fourth surface, a third-first surface through which the light beam of said optical path for the right eye exits from the prism, and a third-second surface through which the light beam of said optical path for the left eye exits from the prism, said optical path distributing prism being arranged so that at least said second-first surface, said second-second surface, said third-first surface, said third-second surface and said fourth surface have a curved surface configuration that gives a power to a light beam, and said second-first surface and said second-second surface have a same surface configuration and said third-first surface and said third-second surface have a same surface configuration, said image display device being a reflection type image display device that displays an image by reflecting a light beam from a light source, wherein said fourth surface of said optical path distributing prism is either a semitransparent reflecting surface or a partially-transmitting and partially-reflecting surface, and wherein an illuminating light source for forming the optical path for the left eye and an illuminating light source for forming the optical path for the right eye are disposed at respective positions on a side of said fourth surface remote from the prism medium.

48. An image display apparatus comprising an image display device for displaying an image to be observed by an observer, an optical path distributing prism for distributing said image to an optical path for a right eye and an optical path for a left eye, an ocular prism for the right eye that is placed on a right-hand side of said optical path distributing prism, and an ocular prism for the left eye that is placed on a left-hand side of said optical path distributing prism, said optical path distributing prism having a first surface placed to face said image display device so that a display light beam emanating from said image display device enters the prism through the first surface, a second surface wherein said optical path for the right eye is made incident on an optical surface at an angle larger than a total reflection critical angle to reflect a light beam of the optical path for the right eye within the prism by total reflection and said optical path for the left eye is made incident on the optical surface at an angle smaller than the total reflection critical angle to allow a light beam of the optical path for the left eye to exit from the prism, and a third surface wherein said optical path for the left eye is made incident on an optical surface at an angle larger than a total reflection critical angle to reflect the light beam of the optical path for the left eye within the prism by total reflection and said optical path for the right eye is made incident on the optical surface at an angle smaller than the total reflection critical angle to allow the light beam of the optical path for the right eye to exit from the prism, wherein an optical element for display is placed between said image display device and said first surface, said optical path distributing prism being arranged so that said second surface and said third surface are curved surfaces of a same configuration that gives a power to a light beam, and said second surface and said third surface are placed to face each other across a prism medium, said image display device being a transmission type image display device that displays an image by transmitting a light beam from a light source, wherein an illuminating light source for forming the optical path for the left eye and an illuminating light source for forming the optical path for the right eye are disposed at respective positions on a side of said image display device remote from said optical element for display.

49. An image display apparatus according to claim 48, wherein said optical element for display is a Fresnel lens.

50. An image display apparatus according to claim 46, wherein both said second-first surface and second-second surface of said optical path distributing prism are formed from half-mirror coatings that divide transmission and reflection in terms of intensity.

51. An image display apparatus according to claim 46, wherein both said second-first surface and second-second surface of said optical path distributing prism are formed from mirror coatings each having transmitting holes provided in a reflecting mirror surface.

52. An image display apparatus according to claim 47, wherein the fourth surface of said optical path distributing prism is formed from a half-mirror coating that divides transmission and reflection in terms of intensity.

53. An image display apparatus according to claim 47, wherein the fourth surface of said optical path distributing prism is formed from a mirror coating having transmitting holes provided in a reflecting mirror surface.

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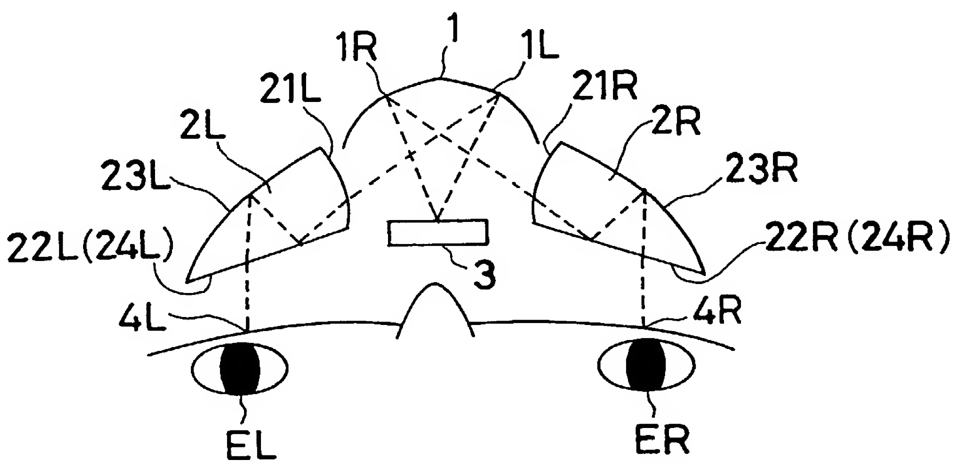
(54) Title: IMAGE DISPLAY

(54) 発明の名称: 画像表示装置



(57) Abstract: An image display such as a head-mounted image display for allowing the user to view with both user's eyes an image displayed on one image display element by directing the image to both user's eyes without providing any half-silvered mirror. The image display comprises an optical path branching mirror (1) for distributing the image on one display element (10) to a right-eye optical path and a left-eye optical path, a right-eye ocular prism (2R) on the left side, and a left-eye ocular prism (2L) on the left side. Along the right-eye optical path, the display light from the display element (3) is reflected from the reflecting surface (1R) of the optical path branching mirror (1), passed through a first surface (21R) of a decentered prism (2R), made to enter the prism, total-reflected from a second surface (22R), back-reflected from a third surface (23R), made to exit from the prism through a fourth surface (24R) which the second surface (22R) serves as, directed to an exit pupil (4R) for the right eye, and projected to the right eye to form a magnified image of the image on the display element (3). As for the left-eye optical path, the display light travels similarly.

[続葉有]

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(57) 要約:

本発明は、１つの画像表示素子からの画像を、ハーフミラーを利用せずに両眼に導き明るく観察できる頭部装着式画像表示装置等の画像表示装置に関し、１枚の表示素子（１０）の画像を右眼用光路と左眼用光路とに振分ける光路振分けミラー（１）と、その右側の右眼用接眼プリズム（２R）と、その左側の左眼用接眼プリズム（２L）とを有し、右眼用の光路においては、表示素子（３）からの表示光は、光路振分けミラー（１）の反射面（１R）で反射され、偏心プリズム体（２R）の第１面（２１R）を透過してプリズム内に入射し、第２面（２２R）で全反射され、第３面（２３R）で裏面反射され、第２面（２２R）が兼ねる第４面（２４R）を経てプリズム外に射出し、右眼用の射出瞳（４R）へ導かれ、右眼に表示素子（３）の拡大像を投影する。左眼用の光路も同様。

明　細　書

画像表示装置

技　術　分　野

本発明は、画像表示装置に関し、特に、観察者の頭部又は顔面に保持することを可能にする頭部又は顔面装着式画像表示装置に関する。

背　景　技　術

従来、１つの画像表示素子の画像を両眼で観察する画像表示装置としては、特開平５－１７６２６０号、特開平９－６１７４８号、特開平９－１８１９９８号、特開平９－１８１９９９号において知られている。

また、１つの画像表示素子の画像を両眼で観察する画像表示装置の照明方法としては、例えば特開平７－３１８８５１号において知られている。

この中、特開平５－１７６２６０号のものでは、二等辺三角柱のプリズムとミラーで光線を分割し、折り曲げているので、諸収差の補正は、瞳の前に配置するレンズで行うことになり、補正が難しくなると同時に、装置の大型化を招く。また、特開平９－６１７４８号のものでは、ＬＣＤ（液晶表示素子）の表示光をハーフミラーを利用して分割して両眼で観察する。そのために、左右それぞれの眼球へ表示光が分かれるので、観察像が弱く暗くなる。また、特開平９－１８１９９８号、特開平９－１８１９９９号のものは、プリズムが１体化であるため非常に大きく、射出成形で製作する場合、非常に時間がかかりコスト高になる。また偏心収差の補正が不充分である。

また、単一の表示素子からの表示像を両眼で観察する場合の照明方法では、特

開平７－３１８８５１号のような構成をとった場合、左右の眼に導かれる画像が右左逆になってしまうため、表示素子等で電気的に表示を切り換える必要がある。

発 明 の 開 示

本発明は従来技術のこのような問題点に鑑みてなされたものであり、その目的は、１つの画像表示素子からの画像を、ハーフミラーを利用せずに両眼に導き明るく観察でき、さらに、両眼の中央に配置する光路振り分け手段にパワーを持たせることで、諸収差の補正を容易にした、頭部装着式画像表示装置等の画像表示装置を提供することである。また、表示画像を左右で切り換えずに使用できる単板（単一の画像表示素子）両眼視に最適な照明方法を提供することである。

上記目的を達成する本発明の画像表示装置は、観察者が観察する画像を表示する画像表示素子と、前記画像を右眼用光路と左眼用光路とに振分ける光路振分けミラーと、前記光路振分けミラーの右側に配置された右眼用接眼プリズムと、前記光路振分けミラーの左側に配置された左眼用接眼プリズムとを有し、

前記光路振分けミラーが、前記画像表示素子に対向配置され前記画像表示素子から射出された表示光束を、前記右眼用接眼プリズムと前記左眼用プリズムとに振分けて反射するミラー面を有し、前記ミラー面が、偏心収差を補正する回転非対称な曲面形状にて構成され、

前記右眼用接眼プリズムが、前記光路振分けミラーで反射された右眼用光路の光束をプリズム内に入射させる第１面と、プリズム内で右眼用光路の光束を反射する第２面と、プリズム外に右眼用光路の光束を射出する第３面とを有し、

前記左眼用接眼プリズムが、前記光路振分けミラーで反射された左眼用光路の光束をプリズム内に入射させる第１面と、プリズム内で左眼用光路の光束を反射する第２面と、プリズム外に左眼用光路の光束を射出する第３面とを有し、

少なくとも、前記右眼用接眼プリズムの反射作用面である第２面と、前記左眼用接眼プリズムの反射作用面である第２面とが、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とするものである。

本発明のもう１つの画像表示装置は、観察者が観察する画像を表示する画像表示素子と、前記画像を右眼用光路と左眼用光路とに振分ける光路振分けプリズムと、前記光路振分けプリズムの右側に配置された右眼用接眼プリズムと、前記光路振分けプリズムの左側に配置された左眼用接眼プリズムとを有し、

前記光路振分けプリズムが、前記画像表示素子に対向配置され前記画像表示素子から射出された表示光束をプリズム内部に入射させる第１面と、前記第１面から入射した前記右眼用光路を反射する第２１面と、前記第１面から入射した前記左眼用光路を反射する第２２面と、前記右眼用光路の光束をプリズム外に射出させる第３１面と、前記左眼用光路の光束をプリズム外に射出させる第３２面と、を少なくとも有し、

前記光路振分けプリズムは、前記右眼用光路中に前記画像表示素子の表示した像から右眼用リレー像を形成し、かつ、前記左眼用光路中に前記画像表示素子の表示した像から左眼用リレー像を形成するために、少なくとも前記第２１面と前記第２２面とが、光束にパワーを与える曲面形状にて構成されると共に、前記第２１面と前記第２２面とが同一の面形状を有するように構成され、

前記右眼用接眼プリズムが、前記光路振分けプリズムの前記第３１面から射出された右眼用光路の光束をプリズム内に入射させる第１面と、プリズム内で右眼用光路の光束を反射する第２面と、プリズム外に右眼用光路の光束を射出する第３面とを有し、

前記左眼用接眼プリズムが、前記光路振分けプリズムの前記第３２面から射出された左眼用光路の光束をプリズム内に入射させる第１面と、プリズム内で左眼用光路の光束を反射する第２面と、プリズム外に左眼用光路の光束を射出する第３面とを有し、

少なくとも、前記右眼用接眼プリズムの反射作用面である第２面と、前記左眼用接眼プリズムの反射作用面である第２面とが、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とするものである。

本発明においては、以上のような構成であるので、１つの画像表示素子からの画像を、ハーフミラーを利用せずに両眼に導き明るく観察でき、さらに、両眼の

中央に配置する光路振分けミラーあるいは光路振分けプリズムを持たせることで、諸収差の補正を容易にして、頭部装着式画像表示装置等の画像表示装置を提供することができる。また、このような構成において、表示画像を左右で切り換えずに使用できる単板両眼視に最適な照明配置を得ることができる。

Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification.

The invention accordingly comprises the features of construction, combinations of elements, and arrangement of parts which will be exemplified in the constrution hereinafter set forth, and the scope of the invention will be indicated in the claims.

図面の簡単な説明

図１は本発明による実施例１の画像表示装置の光路図である。

図２は本発明による実施例２の画像表示装置の光路図である。

図３は本発明による実施例３の画像表示装置の光路図である。

図４は本発明による実施例４の画像表示装置の光路図である。

図５は本発明による実施例５の画像表示装置の光路図である。

図６は本発明による実施例６の画像表示装置の光路図である。

図７は本発明による実施例７の画像表示装置の光路図である。

図８は本発明による実施例８の画像表示装置の光路図である。

図９は本発明による実施例９の画像表示装置の光路図である。

図１０は本発明による実施例１０の画像表示装置の光路図である。

図１１は本発明による実施例１１の画像表示装置の光路図である。

図１２は本発明による実施例１２の画像表示装置の光路図である。

図１３は本発明による実施例１３の画像表示装置の光路図である。

図１４は本発明による実施例１４の画像表示装置の光路図である。

図１５は本発明による実施例１５の画像表示装置の光路図である。

図１６は本発明による実施例１６の画像表示装置を説明するための図である。

図１７は本発明の実施例１７の画像表示装置の両眼の光学系を示す水平断面図である。

図１８は本発明の実施例１８の画像表示装置の両眼の光学系を示す水平断面図である。

図１９は本発明の実施例１９の画像表示装置の両眼の光学系を示す水平断面図である。

図２０は本発明の実施例２０の画像表示装置の両眼の光学系を示す水平断面図である。

図２１は本発明の実施例２１の画像表示装置の両眼の光学系を示す水平断面図である。

図２２は本発明の実施例２２の画像表示装置の両眼の光学系を示す水平断面図である。

図２３は本発明の実施例２３の画像表示装置の両眼の光学系を示す水平断面図である。

図２４は本発明の実施例２４の画像表示装置の両眼の光学系を示す水平断面図である。

図２５は本発明の実施例２５の画像表示装置の両眼の光学系を示す水平断面図である。

図２６は本発明の実施例２６の画像表示装置の両眼の光学系を示す水平断面図である。

図２７は本発明の実施例２７の画像表示装置の両眼の光学系を示す水平断面図である。

図２８は本発明の実施例２８の画像表示装置の両眼の光学系を示す水平断面図である。

図２９は本発明による実施例２９～３０の画像表示装置の光路図である。

図３０はパラメータαとβの定義を説明するための図である。

図３１はパラメータＬとＤの定義を説明するための図である。

図３２は実施例２９の右眼用の光学系の水平断面図である。

図３３は実施例３０の右眼用の光学系の水平断面図である。

図３４は実施例１６の光学系の横収差図である。

図３５は実施例２０の光学系の横収差図である。

図３６は実施例２２の光学系の横収差図である。

図３７は実施例２９の光学系の横収差図である。

図３８は実施例３０の光学系の横収差図である。

図３９は本発明の画像表示装置をシースルー観察可能に構成した場合の構成を説明するための図である。

図４０は有機ＥＬ画像表示素子の構造を例示する斜視図である。

図４１は本発明の画像表示装置を観察者頭部に装着した場合の様子を示す図である。

発明を実施するための最良の形態

以下に、本発明の画像表示装置を実施例に基づいて説明する。図１～図１５にそれぞれ本発明による実施例１～１６の画像表示装置の光路図を示す。

図１の実施例１において、観察者の右眼をＥＲで、左眼をＥＬで、画像表示装置の画像表示素子を符号３で、右眼用の射出瞳を４Ｒで、左眼用の射出瞳を４Ｌで示し、右眼用の光学系で右眼前に配置する偏心プリズム体を２Ｒ、左眼用の光学系で左眼前に配置する偏心プリズム体を２Ｌで示す。さらに、両眼の中央に配置する光路振分けミラーを１で示す。偏心プリズム体２Ｒ、２Ｌは屈折率が１より大きい透明媒体からなっている。また、下記の説明において、反射面と説明している面は、全反射面以外は偏心プリズム体の対象の面にミラーコートを施してミラー面としたものである。

この実施例１は、図１に水平断面（Ｙ－Ｚ断面）を示すような構成になっており、中央の光路振分けミラー１は、両眼の対称面（右眼用射出瞳４Ｒと左眼用射出瞳４Ｌの中心間を結んだ線分の中心を通りその線分に垂直な平面）に対して面対称な形状の右光路用反射面１Ｒと左光路用反射面１Ｌとからなる。

右眼用の光学系を構成する偏心プリズム体２Ｒと左眼用の光学系を構成する偏

心プリズム体２Ｌとは同一形状のもので、両眼の対称面に対して面対称に配置され、それぞれ光線が通る順番で、第１面２１Ｒ（２１Ｌ）、第２面２２Ｒ（２２Ｌ）、第３面２３Ｒ（２３Ｌ）、第４面２４Ｒ（２４Ｌ）から構成されており、第２面２２Ｒ（２２Ｌ）と第４面２４Ｒ（２４Ｌ）は同一面からなり、その同一面は全反射面と透過面を兼ねている。

画像表示素子３は、光路振分けミラー１に面してその観察者側に配置される。偏心プリズム体２Ｒ、２Ｌの第４面２４Ｒ、２４Ｌそれぞれに面して略同一面上に射出瞳４Ｒ、４Ｌが位置している。そして、各偏心プリズム体２Ｒ、２Ｌ、光路振分けミラー１の各面２１Ｒ～２４Ｒ、２１Ｌ～２４Ｌ、１Ｒ、１Ｌは、後記の式（ａ）で表される自由曲面から構成されている。また、各自由曲面は、平面を含む球面、非球面、アナモフィック面、アナモフィック非球面に置き換えることも可能である。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面対称であるので、右眼用の光路を代表的に説明する。共通の１枚の画像表示素子３からの表示光は、まず、光路振分けミラー１の反射面１Ｒに入射して反射され、偏心プリズム体２Ｒに入射する。入射光は第１面２１Ｒを透過してプリズム内に入射し、第２面２２Ｒに臨界角以上の入射角で入射して全反射され、第３面２３Ｒに入射して裏面反射され、第４面２４Ｒに臨界角以下の入射角で入射して屈折されて偏心プリズム体２Ｒから射出し、右眼用の射出瞳４Ｒへ導かれ、観察者の右眼に画像表示素子３の拡大像を投影する。なお、画像表示素子３から射出瞳４Ｒへ到る光路中には中間像は結像されない。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子３からの表示光は、３回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも１面が正パワーを有する反射面及び透過面を経て画像表示素子３の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、左右の光路振分けのために光路振分けミラ

ー１の１面にすることで、多数面あるプリズムより製造が簡単で表示装置を軽量化できる利点がある。また、画像表示素子３が観察者側に位置するため、表示装置全体が前へ大きく出っ張らない。さらに、特開平９－６１７４８号のようにハーフミラーを利用せず、共通の１枚の画像表示素子３からの表示画像を両眼に明るく導くことが可能である。また、光路振分けミラー１の反射面１Ｒ、１Ｌに自由曲面を用いることにより、偏心収差を非常に良好に補正することが可能になる。

さらに、偏心プリズム体２Ｒ、２Ｌは面対称な位置に配置されるが、その形状は同一なものである、同じ形状の２つの偏心プリズム体２Ｒ、２Ｌを用意し、中央の光路振分けミラー１に対して面対称な位置に配置すればよい。

実施例２は、図２に水平断面（Ｙ－Ｚ断面）を示すように、実施例１の配置において、画像表示素子３から光路振分けミラー１の右光路用反射面１Ｒと左光路用反射面１Ｌに至る光路中に共通の負レンズ５を挿入したもので、その他の配置、光路は実施例１と同じであり、同様に中間像は結像されない。この負レンズ５の代わりにあるいはそれに加えて回折光学素子やレンチキュラーレンズを用いてもよい。画像表示素子３から光路振分けミラー１の間に負レンズ５等を挿入することにより、収差補正がさらに良好になる。また、回折光学素子やレンチキュラーレンズを用いることにより、左右の光路分割がよりしやすくなる。

実施例３は、図３に水平断面（Ｙ－Ｚ断面）を示すように、実施例１～２の両眼の中央に配置する光路振分けミラー１の代わりに、５面の偏心プリズム体からなる光路振分けプリズム１０を用いたものである。左右の眼用の偏心プリズム体２Ｌ、２Ｒは実施例１～２と同様である。

中央の光路振分けプリズム１０は、両眼の対称面に対して面対称な形状であり、画像表示素子３の観察者側に位置する第１面１１が透過面、その第１面１１の両側で観察者側に位置する右光路用反射面の第２面１２Ｒと左光路用反射面の第２面１２Ｌ、さらにそれら第２面１２Ｒ、１２Ｌの観察者側に位置する左光路用透過面１３Ｌ、右光路用透過面１３Ｒの５面からなる。第１面１１は両眼の対称面に対して面対称な形状、第２面１２Ｒと１２Ｌは両眼の対称面に対して面対称

な形状、第３面１３Ｌと１３Ｒは両眼の対称面に対して面対称な形状である。画像表示素子３は、光路振分けプリズム１０の第１面１１に面して、光路振分けプリズム１０の観察者とは反対側に配置される。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面対称であるので、右眼用の光路を代表的に説明する。共通の１枚の画像表示素子３からの表示光は、まず、光路振分けプリズム１０の第１面１１に入射し、その右光路用反射面の第２面１２Ｒに入射して反射され、右光路用透過面１３Ｒを透過して、偏心プリズム体２Ｒに入射する。入射光は第１面２１Ｒを透過してプリズム内に入射し、第２面２２Ｒに臨界角以上の入射角で入射して全反射され、第３面２３Ｒに入射して裏面反射され、第４面２４Ｒに臨界角以下の入射角で入射して屈折されて偏心プリズム体２Ｒから射出し、右眼用の射出瞳４Ｒへ導かれ、観察者の右眼に画像表示素子３の拡大像を投影する。この場合に、画像表示素子３から射出瞳４Ｒへ到る光路中に１回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子３からの表示光は、３回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも１面が正パワーを有する反射面及び透過面を経て画像表示素子３の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、中間結像がない場合はバックフォーカスの確保が難しく、また、広い画角が取れなかったが、この例の場合は中間像を１回結像するようにしたので、広い画角においても良好な収差補正が可能となる。また、光路振分けプリズム１０の射出面と反射面が共有ではないため、偏心収差を良好に補正することができる。また、光路振分けプリズム１０の反射面１２Ｒ、１２Ｌは全反射を用いていないため、面に対する入射角を小さくすることができ、面の製造精度を緩くすることが可能である。さらに、画像表示素子３が観察者から離れて位置するので、観察者の鼻との干渉を受けない。さらに、特開平９－

６１７４８号のようにハーフミラーを利用せず、共通の１枚の画像表示素子３からの表示画像を両眼に明るく導くことが可能である。また、光路振分けプリズム１０の反射面１２Ｒ、１２Ｌに自由曲面を用いることにより、偏心収差を非常に良好に補正することが可能になる。

さらに、左右何れの光路も大部分、屈折率が１より大きい透明媒体で満たされた偏心プリズム体１０、２Ｒ、２Ｌ中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。また、偏心プリズム体２Ｒ、２Ｌは面対称な位置に配置されるが、その形状は同一なものである、同じ形状の２つの偏心プリズム体２Ｒ、２Ｌを用意し、中央の偏心プリズム体１０に対して面対称な位置に配置すればよい。

実施例４は、図４に水平断面（Ｙ－Ｚ断面）を示すように、実施例１～２の両眼の中央に配置する光路振分けミラー１の代わりに、５面の偏心プリズム体からなる光路振分けプリズム１０を用いたものである。左右の眼用の偏心プリズム体２Ｌ、２Ｒは実施例１～２と同様である。実施例３との大きな違いは、画像表示素子３が、光路振分けプリズム１０の観察者側に配置されている点である。

中央の光路振分けプリズム１０は、両眼の対称面に対して面対称な形状であり、画像表示素子３の観察者と反対側に位置する第１面１１が透過面、その第１面１１の両側で観察者と反対側に位置する右光路用透過面の第３面１３Ｒ、左光路用透過面の第３面１３Ｌ、さらにそれら第３面１３Ｒ、１３Ｌの観察者と反対側に位置する左光路用反射面の第２面１２Ｌと右光路用反射面の第２面１２Ｒの５面からなる。第１面１１は両眼の対称面に対して面対称な形状、第３面１３Ｒと１３Ｌ、第２面１２Ｌと１２Ｒは両眼の対称面に対して面対称な形状である。画像表示素子３は、光路振分けプリズム１０の第１面１１に面して、光路振分けプリズム１０の観察者側に配置される。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面対称であるので、右眼用の光路を代表的に説明する。共通の１枚の画像表示素子３からの表示光は、まず、光路振分けプリズム１０の第１面１１に入射し、その右光路用反射面の第２面１２Ｒに入射して反射され、右光路用透過面１３Ｒを透過し

て、偏心プリズム体２Ｒに入射する。入射光は第１面２１Ｒを透過してプリズム内に入射し、第２面２２Ｒに臨界角以上の入射角で入射して全反射され、第３面２３Ｒに入射して裏面反射され、第４面２４Ｒに臨界角以下の入射角で入射して屈折されて偏心プリズム体２Ｒから射出し、右眼用の射出瞳４Ｒへ導かれ、観察者の右眼に画像表示素子３の拡大像を投影する。この場合に、画像表示素子３から射出瞳４Ｒへ到る光路中に１回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子３からの表示光は、３回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも１面が正パワーを有する反射面及び透過面を経て画像表示素子３の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、中間結像がない場合はバックフォーカスの確保が難しく、また、広い画角が取れなかったが、この例の場合は中間像を１回結像するようにしたので、広い画角においても良好な収差補正が可能となる。また、光路振分けプリズム１０の射出面と反射面が共有ではないため、偏心収差を良好に補正することができる。また、光路振分けプリズム１０の反射面１２Ｒ、１２Ｌは全反射を用いていないため、面に対する入射角を小さくすることができ、面の製造精度を緩くすることが可能である。また、画像表示素子３が観察者側に位置するため、表示装置全体が前へ大きく出っ張らない。さらに、特開平９－６１７４８号のようにハーフミラーを利用せず、共通の１枚の画像表示素子３からの表示画像を両眼に明るく導くことが可能である。また、光路振分けプリズム１０の反射面１２Ｒ、１２Ｌに自由曲面を用いることにより、偏心収差を非常に良好に補正することが可能になる。

さらに、左右何れの光路も大部分、屈折率が１より大きい透明媒体で満たされた偏心プリズム体１０、２Ｒ、２Ｌ中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。また、偏

心プリズム体２Ｒ、２Ｌは面対称な位置に配置されるが、その形状は同一なものである、同じ形状の２つの偏心プリズム体２Ｒ、２Ｌを用意し、中央の偏心プリズム体１０に対して面対称な位置に配置すればよい。

実施例５は、図５に水平断面（Ｙ－Ｚ断面）を示すように、実施例３～４の５面の偏心プリズム体からなる光路振分けプリズム１０の代わりに３面の偏心プリズム体からなる光路振分けプリズム１０を用いたものである。左右の眼用の偏心プリズム体２Ｌ、２Ｒは実施例１～４と同様である。

中央の光路振分けプリズム１０は、両眼の対称面に対して面対称な形状であり、画像表示素子３の観察者側に位置する第１面１１が透過面、その第１面１１の両側で観察者側に位置する全反射面として作用する右光路用反射面の第２面１２Ｒと左光路用反射面の第２面１２Ｌ、右光路用反射面の第２面１２Ｒと同一面の左光路用透過面１３Ｌ、左光路用反射面の第２面１２Ｌと同一面の右光路用透過面１３Ｒの３面からなる。第１面１１は両眼の対称面に対して面対称な形状、第２面１２Ｒ（１３Ｌ）と１２Ｌ（１３Ｒ）は両眼の対称面に対して面対称な形状である。画像表示素子３は、光路振分けプリズム１０の第１面１１に面して、光路振分けプリズム１０の観察者とは反対側に配置される。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面対称であるので、右眼用の光路を代表的に説明する。共通の１枚の画像表示素子３からの表示光は、まず、光路振分けプリズム１０の第１面１１に入射し、その右光路用反射面の第２面１２Ｒに入射して全反射され、右光路用透過面１３Ｒ（１２Ｌ）を透過して、偏心プリズム体２Ｒに入射する。入射光は第１面２１Ｒを透過してプリズム内に入射し、第２面２２Ｒに臨界角以上の入射角で入射して全反射され、第３面２３Ｒに入射して裏面反射され、第４面２４Ｒに臨界角以下の入射角で入射して屈折されて偏心プリズム体２Ｒから射出し、右眼用の射出瞳４Ｒへ導かれ、観察者の右眼に画像表示素子３の拡大像を投影する。この場合に、画像表示素子３から射出瞳４Ｒへ到る光路中に１回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子３からの表示光は、３回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも１面が正パワーを有する反射面及び透過面を経て画像表示素子３の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、中間結像がない場合はバックフォーカスの確保が難しく、また、広い画角が取れなかったが、この例の場合は中間像を１回結像するようにしたので、広い画角においても良好な収差補正が可能となる。また、光路振分けプリズム１０の射出面と反射面が兼用面であるため、光路振分けプリズム１０の有効面が３面のみであるため、製造が非常に簡単である。さらに、画像表示素子３が観察者から離れて位置するので、観察者の鼻との干渉を受けない。さらに、特開平９－６１７４８号のようにハーフミラーを利用せず、共通の１枚の画像表示素子３からの表示画像を両眼に明るく導くことが可能である。また、光路振分けプリズム１０の反射面１２Ｒ、１２Ｌに自由曲面を用いることにより、偏心収差を非常に良好に補正することが可能になる。

さらに、左右何れの光路も大部分、屈折率が１より大きい透明媒体で満たされた偏心プリズム体１０、２Ｒ、２Ｌ中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。また、偏心プリズム体２Ｒ、２Ｌは面対称な位置に配置されるが、その形状は同一なものである、同じ形状の２つの偏心プリズム体２Ｒ、２Ｌを用意し、中央の偏心プリズム体１０に対して面対称な位置に配置すればよい。

実施例６は、図６に水平断面（Ｙ－Ｚ断面）を示すように、実施例３～４の５面の偏心プリズム体からなる光路振分けプリズム１０の代わりに６面の偏心プリズム体からなる光路振分けプリズム１０を用いたものである。左右の眼用の偏心プリズム体２Ｌ、２Ｒは実施例１～５と同様である。

中央の光路振分けプリズム１０は、両眼の対称面に対して面対称な形状であり、画像表示素子３の観察者側に位置する第１面１１が透過面、その第１面１１に面していて観察者に面する反射面の第２面１２、第１面１１の観察者側両側に配

置された右光路用反射面の第３面１３Ｒと左光路用反射面の第３面１３Ｌ、第３面１３Ｒ、１３Ｌと第２面１２の間の両側に配置された左光路用透過面の第４面１４Ｌ、右光路用透過面の第４面１４Ｒの６面からなる。第１面１１、第２面１２は両眼の対称面に対して面対称な形状、第３面１３Ｒと１３Ｌ、第４面１４Ｌと１４Ｒは両眼の対称面に対して面対称な形状である。画像表示素子３は、光路振分けプリズム１０の第１面１１に面して、光路振分けプリズム１０の観察者とは反対側に配置される。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面対称であるので、右眼用の光路を代表的に説明する。共通の１枚の画像表示素子３からの表示光は、まず、光路振分けプリズム１０の左右共通の第１面１１に入射し、左右共通の第２面１２で反射され、右光路用反射面の第３面１３Ｒに入射して反射され、右光路用透過面１４Ｒを透過して、偏心プリズム体２Ｒに入射する。入射光は第１面２１Ｒを透過してプリズム内に入射し、第２面２２Ｒに臨界角以上の入射角で入射して全反射され、第３面２３Ｒに入射して裏面反射され、第４面２４Ｒに臨界角以下の入射角で入射して屈折されて偏心プリズム体２Ｒから射出し、右眼用の射出瞳４Ｒへ導かれ、観察者の右眼に画像表示素子３の拡大像を投影する。この場合に、画像表示素子３から射出瞳４Ｒへ到る光路中に１回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

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差の補正が可能である。さらに、画像表示素子３が観察者から離れて位置するので、観察者の鼻との干渉を受けない。さらに、特開平９－６１７４８号のようにハーフミラーを利用せず、共通の１枚の画像表示素子３からの表示画像を両眼に明るく導くことが可能である。また、光路振分けプリズム１０の反射面１２、１３Ｒ、１３Ｌに自由曲面を用いることにより、偏心収差を非常に良好に補正することが可能になる。

さらに、左右何れの光路も大部分、屈折率が１より大きい透明媒体で満たされた偏心プリズム体１０、２Ｒ、２Ｌ中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。また、偏心プリズム体２Ｒ、２Ｌは面対称な位置に配置されるが、その形状は同一なものである、同じ形状の２つの偏心プリズム体２Ｒ、２Ｌを用意し、中央の偏心プリズム体１０に対して面対称な位置に配置すればよい。

実施例７は、図７に水平断面（Ｙ－Ｚ断面）を示すように、右眼用の光学系を構成する偏心プリズム体２Ｒと左眼用の光学系を構成する偏心プリズム体２Ｌとは同一形状のもので、両眼の対称面に対して面対称に配置され、それぞれ光線が通る順番で、第１面２１Ｒ（２１Ｌ）、第２面２２Ｒ（２２Ｌ）、第３面２３Ｒ（２３Ｌ）、第４面２４Ｒ（２４Ｌ）、第５面２５Ｒ（２５Ｌ）から構成されており、第３面２３Ｒ（２３Ｌ）と第５面２５Ｒ（２５Ｌ）は同一面からなり、その同一面は全反射面と透過面を兼ねている。

中央の光路振分けプリズム１０は、実施例４（図４）と同様に、両眼の対称面に対して面対称な形状であり、画像表示素子３の観察者側に位置する第１面１１が透過面、その第１面１１の両側で観察者側に位置する右光路用透過面の第３面１３Ｒ、左光路用透過面の第３面１３Ｌ、さらにそれら第３面１３Ｒ、１３Ｌの観察者側に位置する左光路用反射面の第２面１２Ｌと右光路用反射面の第２面１２Ｒの５面からなる。第１面１１は両眼の対称面に対して面対称な形状、第３面１３Ｒと１３Ｌ、第２面１２Ｌと１２Ｒは両眼の対称面に対して面対称な形状である。画像表示素子３は、光路振分けプリズム１０の第１面１１に面して、光路振分けプリズム１０の観察者と反対側に配置される。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面対称であるので、右眼用の光路を代表的に説明する。共通の１枚の画像表示素子３からの表示光は、まず、光路振分けプリズム１０の第１面１１に入射し、その右光路用反射面の第２面１２Ｒに入射して反射され、右光路用透過面１３Ｒを透過して、偏心プリズム体２Ｒに入射する。入射光は第１面２１Ｒを透過してプリズム内に入射し、第２面２２Ｒで反射され、その反射光は第３面２３Ｒに臨界角以上の入射角で入射して全反射され、第４面２４Ｒに入射して裏面反射され、第５面２５Ｒに臨界角以下の入射角で入射して屈折されて偏心プリズム体２Ｒから射出し、右眼用の射出瞳４Ｒへ導かれ、観察者の右眼に画像表示素子３の拡大像を投影する。この場合に、画像表示素子３から射出瞳４Ｒへ到る光路中に１回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子３からの表示光は、４回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも１面が正パワーを有する反射面及び透過面を経て画像表示素子３の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、中間結像がない場合はバックフォーカスの確保が難しく、また、広い画角が取れなかったが、この例の場合は中間像を１回結像するようにしたので、広い画角においても良好な収差補正が可能となる。また、光路振分けプリズム１０の射出面と反射面が共有ではないため、偏心収差を良好に補正することができる。また、光路振分けプリズム１０の反射面１２Ｒ、１２Ｌは全反射を用いていないため、面に対する入射角を小さくすることができ、面の製造精度を緩くすることが可能である。さらに、画像表示素子３が観察者から離れて位置するので、観察者の鼻との干渉を受けない。さらに、特開平９－６１７４８号のようにハーフミラーを利用せず、共通の１枚の画像表示素子３からの表示画像を両眼に明るく導くことが可能である。また、光路振分けプリズム１０の反射面１２Ｒ、１２Ｌに自由曲面を用いることにより、偏心収差を非常に

良好に補正することが可能になる。

さらに、左右何れの光路も大部分、屈折率が1より大きい透明媒体で満たされた偏心プリズム体１０、２Ｒ、２Ｌ中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。また、偏心プリズム体２Ｒ、２Ｌは面対称な位置に配置されるが、その形状は同一なものである、同じ形状の２つの偏心プリズム体２Ｒ、２Ｌを用意し、中央の偏心プリズム体１０に対して面対称な位置に配置すればよい。

実施例８は、図８に水平断面（Ｙ－Ｚ断面）を示すように、実施例７の５面の偏心プリズム体からなる光路振分けプリズム１０の代わりに、実施例５（図５）と同様の３面の偏心プリズム体からなる光路振分けプリズム１０を用いたものである。左右の眼用の偏心プリズム体２Ｌ、２Ｒは実施例７と同様である。

中央の光路振分けプリズム１０は、実施例５（図５）と同様に、両眼の対称面に対して面対称な形状であり、画像表示素子３の観察者と反対側に位置する第１面１１が透過面、その第１面１１の両側で観察者側に位置する全反射面として作用する右光路用反射面の第２面１２Ｒと左光路用反射面の第２面１２Ｌ、右光路用反射面の第２面１２Ｒと同一面の左光路用透過面１３Ｌ、左光路用反射面の第２面１２Ｌと同一面の右光路用透過面１３Ｒの３面からなる。第１面１１は両眼の対称面に対して面対称な形状、第２面１２Ｒ（１３Ｌ）と１２Ｌ（１３Ｒ）は両眼の対称面に対して面対称な形状である。画像表示素子３は、光路振分けプリズム１０の第１面１１に面して、光路振分けプリズム１０の観察者側に配置される。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面対称であるので、右眼用の光路を代表的に説明する。共通の１枚の画像表示素子３からの表示光は、まず、光路振分けプリズム１０の第１面１１に入射し、その右光路用反射面の第２面１２Ｒに入射して全反射され、右光路用透過面１３Ｒ（１２Ｌ）を透過して、偏心プリズム体２Ｒに入射する。入射光は第１面２１Ｒを透過してプリズム内に入射し、第２面２２Ｒで反射され、その反射光は第３面２３Ｒに臨界角以上の入射角で入射して全反射され、第４面２４Ｒに入射して裏面反射

され、第５面２５Ｒに臨界角以下の入射角で入射して屈折されて偏心プリズム体２Ｒから射出し、右眼用の射出瞳４Ｒへ導かれ、観察者の右眼に画像表示素子３の拡大像を投影する。この場合に、画像表示素子３から射出瞳４Ｒへ到る光路中に１回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子３からの表示光は、４回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも１面が正パワーを有する反射面及び透過面を経て画像表示素子３の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、中間結像がない場合はバックフォーカスの確保が難しく、また、広い画角が取れなかったが、この例の場合は中間像を１回結像するようにしたので、広い画角においても良好な収差補正が可能となる。また、光路振分けプリズム１０の射出面と反射面が兼用面であるため、光路振分けプリズム１０の有効面が３面のみであるため、製造が非常に簡単である。また、画像表示素子３が観察者側に位置するため、表示装置全体が前へ大きく出っ張らない。さらに、特開平９－６１７４８号のようにハーフミラーを利用せず、共通の１枚の画像表示素子３からの表示画像を両眼に明るく導くことが可能である。また、光路振分けプリズム１０の反射面１２Ｒ、１２Ｌに自由曲面を用いることにより、偏心収差を非常に良好に補正することが可能になる。

さらに、左右何れの光路も大部分、屈折率が１より大きい透明媒体で満たされた偏心プリズム体１０、２Ｒ、２Ｌ中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。また、偏心プリズム体２Ｒ、２Ｌは面対称な位置に配置されるが、その形状は同一なものである、同じ形状の２つの偏心プリズム体２Ｒ、２Ｌを用意し、中央の偏心プリズム体１０に対して面対称な位置に配置すればよい。

実施例９は、図９に水平断面（Ｙ－Ｚ断面）を示すように、実施例７の５面の偏心プリズム体からなる光路振分けプリズム１０の代わりに、実施例６（図６）

と同様の６面の偏心プリズム体からなる光路振分けプリズム１０を用いたものである。左右の眼用の偏心プリズム体２Ｌ、２Ｒは実施例７と同様である。

中央の光路振分けプリズム１０は、実施例６（図６）と同様に、両眼の対称面に対して面対称な形状であり、画像表示素子３の観察者と反対側に位置する第１面１１が透過面、その第１面１１に面していて観察者と反対側の反射面の第２面１２、第１面１１の観察者と反対側両側に配置された右光路用反射面の第３面１３Ｒと左光路用反射面の第３面１３Ｌ、第３面１３Ｒ、１３Ｌと第２面１２の間の両側に配置された左光路用透過面の第４面１４Ｌ、右光路用透過面の第４面１４Ｒの６面からなる。第１面１１、第２面１２は両眼の対称面に対して面対称な形状、第３面１３Ｒと１３Ｌ、第４面１４Ｌと１４Ｒは両眼の対称面に対して面対称な形状である。画像表示素子３は、光路振分けプリズム１０の第１面１１に面して、光路振分けプリズム１０の観察者側に配置される。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面対称であるので、右眼用の光路を代表的に説明する。共通の１枚の画像表示素子３からの表示光は、まず、光路振分けプリズム１０の左右共通の第１面１１に入射し、左右共通の第２面１２で反射され、右光路用反射面の第３面１３Ｒに入射して反射され、右光路用透過面１４Ｒを透過して、偏心プリズム体２Ｒに入射する。入射光は第１面２１Ｒを透過してプリズム内に入射し、第２面２２Ｒで反射され、その反射光は第３面２３Ｒに臨界角以上の入射角で入射して全反射され、第４面２４Ｒに入射して裏面反射され、第５面２５Ｒに臨界角以下の入射角で入射して屈折されて偏心プリズム体２Ｒから射出し、右眼用の射出瞳４Ｒへ導かれ、観察者の右眼に画像表示素子３の拡大像を投影する。この場合に、画像表示素子３から射出瞳４Ｒへ到る光路中に１回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子３からの表示光は、５回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配

置された少なくとも１面が正パワーを有する反射面及び透過面を経て画像表示素子３の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、中間結像がない場合はバックフォーカスの確保が難しく、また、広い画角が取れなかったが、この例の場合は中間像を１回結像するようにしたので、広い画角においても良好な収差補正が可能となる。また、光路振分けプリズム１０が２回反射の構成であるので、非常に良好に偏心収差の補正が可能である。また、画像表示素子３が観察者側に位置するため、表示装置全体が前へ大きく出っ張らない。さらに、特開平９－６１７４８号のようにハーフミラーを利用せず、共通の１枚の画像表示素子３からの表示画像を両眼に明るく導くことが可能である。また、光路振分けプリズム１０の反射面１２、１３Ｒ、１３Ｌに自由曲面を用いることにより、偏心収差を非常に良好に補正することが可能になる。

さらに、左右何れの光路も大部分、屈折率が１より大きい透明媒体で満たされた偏心プリズム体１０、２Ｒ、２Ｌ中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。また、偏心プリズム体２Ｒ、２Ｌは面対称な位置に配置されるが、その形状は同一なものである、同じ形状の２つの偏心プリズム体２Ｒ、２Ｌを用意し、中央の偏心プリズム体１０に対して面対称な位置に配置すればよい。

実施例１０は、図１０に水平断面（Ｙ－Ｚ断面）を示すように、実施例８（図８）の４面の偏心プリズム体からなる右眼用の偏心プリズム体２Ｒと左眼用の偏心プリズム体２Ｌの代わりに、３面の同一形状の偏心プリズム体からなる右眼用の偏心プリズム体２Ｒと左眼用の偏心プリズム体２Ｌとを、両眼の対称面に対して面対称に配置したもので、光路振分けプリズム１０は同様である。偏心プリズム体２Ｒの第１面２１Ｒを透過してプリズム内に入射した光は、第２面２２Ｒで反射され、その反射光は第３面２３Ｒで屈折されて偏心プリズム体２Ｒから射出し、右眼用の射出瞳４Ｒへ導かれ、観察者の右眼に画像表示素子３の拡大像を投影する。この場合に、画像表示素子３から射出瞳４Ｒへ到る光路中に１回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を

挟んで、右眼用の光路と面対称な関係になる。その他は、実施例８と同じである。

実施例１１は、図１１に水平断面（Ｙ－Ｚ断面）を示すように、実施例７（図７）の４面の偏心プリズム体からなる右眼用の偏心プリズム体２Ｒと左眼用の偏心プリズム体２Ｌの代わりに、３面の同一形状の偏心プリズム体からなる右眼用の偏心プリズム体２Ｒと左眼用の偏心プリズム体２Ｌとを、両眼の対称面に対して面対称に配置したもので、光路振分けプリズム１０は同様である。偏心プリズム体２Ｒの第１面２１Ｒを透過してプリズム内に入射した光は、第２面２２Ｒで反射され、その反射光は第３面２３Ｒで屈折されて偏心プリズム体２Ｒから射出し、右眼用の射出瞳４Ｒへ導かれ、観察者の右眼に画像表示素子３の拡大像を投影する。この場合に、画像表示素子３から射出瞳４Ｒへ到る光路中に１回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。その他は、実施例７と同じである。

実施例１２は、図１２に水平断面（Ｙ－Ｚ断面）を示すように、７面の偏心プリズム体からなる光路振分けプリズム１０を用いたものである。また、右眼用の光学系を構成する偏心プリズム体２Ｒと左眼用の光学系を構成する偏心プリズム体２Ｌとは同一形状のもので、両眼の対称面に対して面対称に配置され、それぞれ光線が通る順番で、第１面２１Ｒ（２１Ｌ）、第２面２２Ｒ（２２Ｌ）、第３面２３Ｒ（２３Ｌ）、第４面２４Ｒ（２４Ｌ）から構成されているものである。

中央の光路振分けプリズム１０は、両眼の対称面に対して面対称な形状であり、観察者と反対側に位置する第１面１１が透過面、その第１面１１の両側で観察者と反対側に位置する右光路用反射面の第３面１３Ｒ、左光路用反射面の第３面１３Ｌ、さらにそれら第３面１３Ｒ、１３Ｌの観察者側に位置する左光路用透過面の第４面１４Ｌと右光路用透過面の第４面１４Ｒ、さらにそれら第４面１４Ｒ、１４Ｌの観察者側に位置する左光路用反射面の第２面１２Ｌと右光路用反射面の第２面１２Ｒの７面からなる。第１面１１は両眼の対称面に対して面対称な形状、第３面１３Ｒと１３Ｌ、第４面１４Ｌと１４Ｒ、第２面１２Ｌと１２Ｒは両

眼の対称面に対して面対称な形状である。画像表示素子３は、光路振分けプリズム１０の第１面１１に面して、光路振分けプリズム１０の観察者とは反対側に配置される。

上記の構成において、破線で示す左右の光路は、両眼の対称面に対して面対称であるので、右眼用の光路を代表的に説明する。共通の１枚の画像表示素子３からの表示光は、まず、光路振分けプリズム１０の第１面１１に入射し、その右光路用反射面の第２面１２Ｒに入射して反射され、次の右光路用反射面の第３面１３Ｒに入射して反射され、右光路用透過面１４Ｒを透過して、偏心プリズム体２Ｒに入射する。入射光は第１面２１Ｒを透過してプリズム内に入射し、第２面２２Ｒに入射して裏面反射され、第３面２３Ｒに入射して裏面反射され、第４面２４Ｒで屈折されて偏心プリズム体２Ｒから射出し、右眼用の射出瞳４Ｒへ導かれ、観察者の右眼に画像表示素子３の拡大像を投影する。この場合に、画像表示素子３から射出瞳４Ｒへ到る光路中に１回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子３からの表示光は、４回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも１面が正パワーを有する反射面及び透過面を経て画像表示素子３の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。また、中間結像がない場合はバックフォーカスの確保が難しく、また、広い画角が取れなかったが、この例の場合は中間像を１回結像するようにしたので、広い画角においても良好な収差補正が可能となる。また、光路振分けプリズム１０の射出面と反射面が共有ではないため、偏心収差を良好に補正することができる。また、光路振分けプリズム１０の反射面１２Ｒ、１２Ｌ、１３Ｒ、１３Ｌは全反射を用いていないため、面に対する入射角を小さくすることができ、面の製造精度を緩くすることが可能である。また、画像表示素子３が観察者から離れて位置するので、観察者の鼻との干渉を受けない。さら

に、特開平９－６１７４８号のようにハーフミラーを利用せず、共通の１枚の画像表示素子３からの表示画像を両眼に明るく導くことが可能である。また、光路振分けプリズム１０の反射面１２Ｒ、１２Ｌ、１３Ｒ、１３Ｌに自由曲面を用いることにより、偏心収差を非常に良好に補正することが可能になる。

さらに、左右何れの光路も大部分、屈折率が１より大きい透明媒体で満たされた偏心プリズム体１０、２Ｒ、２Ｌ中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。また、偏心プリズム体２Ｒ、２Ｌは面対称な位置に配置されるが、その形状は同一なものである、同じ形状の２つの偏心プリズム体２Ｒ、２Ｌを用意し、中央の偏心プリズム体１０に対して面対称な位置に配置すればよい。

この実施例においては、光路振分けプリズム１０、偏心プリズム体２Ｒ、２Ｌ何れにおいても、全反射面を用いていない。全反射面を用いる場合、全反射条件を満足させるためには光線の入射角を非常に大きくする必要がある。しかし、入射角の大きい面にパワーを持たせると偏心収差が大きく発生し、弱いパワーしか持たせることができないが、このような全反射面を用いていない本実施例においては、通常の反射を利用することで各面にパワーを均等に配分し、非常に良好に偏心収差を補正することが可能となる。また、各偏心プリズム１０、２Ｒ、２Ｌ中で光路を交差させているため、接眼プリズムの光路長を大きく取ることができる。そのため、中間結像位置が接眼プリズムの中に形成できる。したがって、中間像から表示素子までの物像間距離が長く取れ、光路振り分けプリズム１０のパワーを弱く設定することができる。そのため、良好な結像性能を確保することができる。

実施例１３～１５は、画像表示素子３の照明光学系に関する実施例であり、図１３の実施例１３は、図５の実施例５の左右の光学系配置において、画像表示素子３として透過型のＬＣＤ（液晶表示素子）を用い、その背後（光路振分けプリズム１０と反対側）に左右の光路用の照明光源６Ｒ、６Ｌを配置し、光源６Ｒ、６Ｌと画像表示素子３の間に集光用フレネルレンズ７を配置した実施例である。

この実施例においては、左光路用の照明光源６Ｌからの照明光はフレネルレン

ズ７で集光されて画像表示素子３に入射し、その表示光は図５の左眼用光路を経て観察者の左眼ＥＬに達し、画像表示素子３の拡大像を投影する。また、右光路用の照明光源６Ｒからの照明光はフレネルレンズ７で集光されて画像表示素子３に入射し、その表示光は図５の右眼用光路を経て観察者の左眼ＥＲに達し、画像表示素子３の拡大像を投影する。

この場合、左右共通の１枚の画像表示素子（ＬＤＣ）３の左右眼用の照明光学系７と光路振分けプリズム１０を共有化することで、光学部材の削減が可能であり、また、小型軽量で明るい表示装置が可能となる。なお、この例の場合は、照明光学系にもハーフミラーを用いていないため、非常に明るい画像表示が可能になる。

図１４の実施例１４は、図６の実施例６の左右の光学系配置において、画像表示素子３として反射型のＬＣＤ（液晶表示素子）３’を用い、光路振分けプリズム１０を横切って照明可能に左右の光路用の照明光源６Ｒ、６Ｌを配置し、光路振分けプリズム１０の第２面１２をハーフミラー面あるいは一部光透過用の穴を空けたミラー面として、その第２面１２と第１面１１とを経て光源６Ｒ、６Ｌからの照明光で反射型ＬＣＤ３’を照明するようにした実施例である。

この実施例においては、左光路用の照明光源６Ｌからの照明光は、光路振分けプリズム１０の第２面１２のハーフミラー面あるいは一部光透過用の穴を空けたミラー面のその穴を経て光路振分けプリズム１０を横切ってその第１面１１を透過して反射型ＬＣＤ３’の表示面に入射し、反射した表示光は図６の左眼用光路を経て観察者の左眼ＥＬに達し、画像表示素子３の拡大像を投影する。また、右光路用の照明光源６Ｒからの照明光も、同様に光路振分けプリズム１０の第２面１２のハーフミラー面あるいは一部光透過用の穴を空けたミラー面のその穴を経て光路振分けプリズム１０を横切ってその第１面１１を透過して反射型ＬＣＤ３’の表示面に入射し、反射した表示光は図６の右眼用光路を経て観察者の右眼ＥＲに達し、画像表示素子３の拡大像を投影する。

この場合、左右共通の１枚の反射型ＬＣＤ３’の左右眼用の照明光学系と光路振分けプリズム１０を共有化することで、光学部材の削減が可能であり、また、

小型軽量で明るい表示装置が可能となる。なお、この例の場合は、光路振分けプリズム（兼用照明プリズム）１０は有効面が６面あるため、反射型ＬＣＤ３’を均一に照明でき、さらに偏心収差を良好に補正することが可能である。

図１５の実施例１５は、図４の実施例４の左右の光学系配置において、画像表示素子３として反射型ＬＣＤ３’を用い、光路振分けプリズム１０を横切って照明可能に左右の光路用の照明光源６Ｒ、６Ｌを配置し、光路振分けプリズム１０の左右の光路用の第２面１２Ｌ、１２Ｒをハーフミラー面あるいは一部光透過用の穴を空けたミラー面として、その第２面１２Ｌ、１２Ｒと第１面１１とを経て光源６Ｒ、６Ｌからの照明光で反射型ＬＣＤ３’を照明するようにした実施例である。

この実施例においては、左光路用の照明光源６Ｌからの照明光は、光路振分けプリズム１０の右眼用光路の第２面１２Ｒのハーフミラー面あるいは一部光透過用の穴を空けたミラー面のその穴を経て光路振分けプリズム１０を横切ってその第１面１１を透過して反射型ＬＣＤ３’の表示面に入射し、反射した表示光は図４の左眼用光路を経て観察者の左眼ＥＬに達し、画像表示素子３の拡大像を投影する。また、右光路用の照明光源６Ｒからの照明光も、同様に光路振分けプリズム１０の左眼用光路の第２面１２Ｌのハーフミラー面あるいは一部光透過用の穴を空けたミラー面のその穴を経て光路振分けプリズム１０を横切ってその第１面１１を透過して反射型ＬＣＤ３’の表示面に入射し、反射した表示光は図４の右眼用光路を経て観察者の右眼ＥＲに達し、画像表示素子３の拡大像を投影する。

この場合、左右共通の１枚の反射型ＬＣＤ３’の左右眼用の照明光学系と光路振分けプリズム１０を共有化することで、光学部材の削減が可能であり、また、小型軽量で明るい表示装置が可能となる。なお、この例の場合は、光路振分けプリズム１０と照明光学系を共有にしながら、照明光学系の入射面及び射出面を共に共有化することで、光路振分けプリズム１０の小型軽量化が可能である。

なお、図１３～図１５のような左右の光路用の照明光源６Ｒ、６Ｌ、集光用フレネルレンズ７の配置、反射面をハーフミラー面あるいは一部光透過用の穴を空けたミラー面として、透過型あるいは反射型の画像表示素子３を照明できること

は、図４～図６の以外の前記実施例においても同様である。

ところで、前記したように、上記のような本発明の画像表示装置用の光学系において、光路振分けミラー１の反射面１Ｒ、１Ｌ、光路振分けプリズム１０の各面１１、１２、１２Ｒ、１２Ｌ、１３Ｒ、１３Ｌ、１４Ｒ、１４Ｌ、右眼用接眼光学系の偏心プリズム体２Ｒの面２１Ｒ～２５Ｒ、右眼用接眼光学系の偏心プリズム体２Ｌの面２１Ｌ～２５Ｌに用いる面としては、偏心収差を補正するような回転非対称な曲面形状にて構成することが望ましい。

ここで、本発明における右眼用接眼プリズム２Ｒ、左眼用接眼プリズム２Ｌ、光路振分けプリズム１０、光路振分けミラー１は、基本的に、偏心光学系であり、偏心収差を補正する回転非対称な曲面形状の光学面を少なくとも１面含むものとして構成するのが望ましい。

偏心光学系を頭部装着式の画像表示装置の観察光学系として用いる場合、デッドスペースをなくし、装置全体をより小型化するためには、画像表示素子の位置、並びに、偏心光学系を構成する光学面の配置位置を、装置内部でなるべくコンパクトに収まる位置に配置する必要がある。そうなると、光学系は必然的に３次元的に偏心した配置とならざるを得ず、回転非対称な収差が発生し、これを回転対称な光学系でのみ補正することは不可能であり、この３次元的な偏心により発生する回転非対称な収差を補正する最良な面形状は回転非対称面である。したがって、本発明の画像表示装置おいては、光路振分けミラー１の反射面１Ｒ、１Ｌ、光路振分けプリズム１０の各面１１、１２、１２Ｒ、１２Ｌ、１３Ｒ、１３Ｌ、１４Ｒ、１４Ｌ、右眼用接眼光学系の偏心プリズム体２Ｒの面２１Ｒ～２５Ｒ、右眼用接眼光学系の偏心プリズム体２Ｌの面２１Ｌ～２５Ｌの中、少なくとも１面、好ましくは反射面の形状を、偏心収差を補正するような回転非対称な曲面形状にて構成することが望ましい。

ここで、回転非対称な曲面形状の面として、本発明で使用する自由曲面とは以下の式で定義されるものである。この定義式のＺ軸が自由曲面の軸となる。

$$Z = c r^2 / [1 + \sqrt{\{1 - (1+k) c^2 r^2\}}] + \sum^{66} C_j X^m Y^n$$

$$j=2$$

・・・（ａ）

ここで、（ａ）式の第１項は球面項、第２項は自由曲面項である。

球面項中、

ｃ：頂点の曲率

ｋ：コーニック定数（円錐定数）

$r=\sqrt{(X^2+Y^2)}$

である。

自由曲面項は、

$$\sum_{j=2}^{66} C_j X^m Y^n$$

$$\begin{aligned}
&=C_2 X+C_3 Y\\
&+C_4 X^2+C_5 XY+C_6 Y^2\\
&+C_7 X^3+C_8 X^2 Y+C_9 XY^2+C_{10}Y^3\\
&+C_{11}X^4+C_{12}X^3 Y+C_{13}X^2 Y^2+C_{14}XY^3+C_{15}Y^4\\
&+C_{16}X^5+C_{17}X^4 Y+C_{18}X^3 Y^2+C_{19}X^2 Y^3+C_{20}XY^4\\
&\qquad+C_{21}Y^5\\
&+C_{22}X^6+C_{23}X^5 Y+C_{24}X^4 Y^2+C_{25}X^3 Y^3+C_{26}X^2 Y^4\\
&\qquad+C_{27}XY^5+C_{28}Y^6\\
&+C_{29}X^7+C_{30}X^6 Y+C_{31}X^5 Y^2+C_{32}X^4 Y^3+C_{33}X^3 Y^4\\
&\qquad+C_{34}X^2 Y^5+C_{35}XY^6+C_{36}Y^7\\
&\qquad\cdots\cdots
\end{aligned}$$

ただし、C_j（ｊは２以上の整数）は係数である。

上記自由曲面は、一般的には、Ｘ－Ｚ面、Ｙ－Ｚ面共に対称面を持つことはないが、Ｘの奇数次項を全て０にすることによって、Ｙ－Ｚ面と平行な対称面が１つだけ存在する自由曲面となる。また、Ｙの奇数次項を全て０にすることによって、Ｘ－Ｚ面と平行な対称面が１つだけ存在する自由曲面となる。

また、上記の回転非対称な曲面形状の面である自由曲面の他の定義式として、Ｚｅｒｎｉｋｅ多項式により定義できる。この面の形状は以下の式（ｂ）により定義する。その定義式（ｂ）のＺ軸がＺｅｒｎｉｋｅ多項式の軸となる。回転非対称面の定義は、Ｘ－Ｙ面に対するＺの軸の高さの極座標で定義され、ＡはＸ－Ｙ面内のＺ軸からの距離、ＲはＺ軸回りの方位角で、Ｚ軸から測った回転角で表せられる。

$$
\begin{aligned}
x &= R \times \cos(A) \\
y &= R \times \sin(A) \\
Z &= D_2 \\
&\quad + D_3 R\cos(A) + D_4 R\sin(A) \\
&\quad + D_5 R^2 \cos(2A) + D_6 (R^2 - 1) + D_7 R^2 \sin(2A) \\
&\quad + D_8 R^3 \cos(3A) + D_9 (3R^3 - 2R)\cos(A) \\
&\qquad + D_{10} (3R^3 - 2R)\sin(A) + D_{11} R^3 \sin(3A) \\
&\quad + D_{12} R^4 \cos(4A) + D_{13} (4R^4 - 3R^2)\cos(2A) \\
&\qquad + D_{14} (6R^4 - 6R^2 + 1) + D_{15} (4R^4 - 3R^2)\sin(2A) \\
&\qquad + D_{16} R^4 \sin(4A) \\
&\quad + D_{17} R^5 \cos(5A) + D_{18} (5R^5 - 4R^3)\cos(3A) \\
&\qquad + D_{19} (10R^5 - 12R^3 + 3R)\cos(A) \\
&\qquad + D_{20} (10R^5 - 12R^3 + 3R)\sin(A) \\
&\qquad + D_{21} (5R^5 - 4R^3)\sin(3A) + D_{22} R^5 \sin(5A) \\
&\quad + D_{23} R^6 \cos(6A) + D_{24} (6R^6 - 5R^4)\cos(4A) \\
&\qquad + D_{25} (15R^6 - 20R^4 + 6R^2)\cos(2A) \\
&\qquad + D_{26} (20R^6 - 30R^4 + 12R^2 - 1) \\
&\qquad + D_{27} (15R^6 - 20R^4 + 6R^2)\sin(2A) \\
&\qquad + D_{28} (6R^6 - 5R^4)\sin(4A) + D_{29} R^6 \sin(6A) \cdots\cdots \\
&\qquad\qquad \cdots\cdots (b)
\end{aligned}
$$

ただし、D_m（ｍは２以上の整数）は係数である。なお、Ｘ軸方向に対称な光学系として設計するには、D_4，D_5，D_6、D_{10}，D_{11}，D_{12}，D_{13}，D_{14}，Ｄ

$_{20}$, D_{21}, D_{22}…を利用する。

上記定義式は、回転非対称な曲面形状の面の例示のために示したものであり、他のいかなる定義式に対しても同じ効果が得られることは言うまでもない。

そして、光路振分けプリズム光路振分けミラー1、光路振分けプリズム１０、右眼用接眼プリズム体２Ｒ、右眼用接眼プリズム体２Ｌの有する自由曲面が、画像表示素子の表示画像中心と瞳中心とを結んだ光線を光軸としたときに、プリズム内での折り返し光路中の光軸を含んだ面（Ｙ－Ｚ平面）を唯一の対称面として構成されていることが望ましい。

なお、自由曲面の他の定義式の例として、次の定義式（ｃ）があげられる。

$$Z=\Sigma\Sigma C_{nm}XY$$

例として、ｋ＝７（７次項）を考えると、展開したとき、以下の式で表せる。

$$\begin{aligned}
Z=\;&C_2\\
&+C_3 Y+C_4 |X|\\
&+C_5 Y^2+C_6 Y|X|+C_7 X^2\\
&+C_8 Y^3+C_9 Y^2 |X|+C_{10}YX^2+C_{11}|X^3|\\
&+C_{12}Y^4+C_{13}Y^3 |X|+C_{14}Y^2 X^2+C_{15}Y|X^3|+C_{16}X^4\\
&+C_{17}Y^5+C_{18}Y^4 |X|+C_{19}Y^3 X^2+C_{20}Y^2 |X^3|\\
&\qquad+C_{21}YX^4+C_{22}|X^5|\\
&+C_{23}Y^6+C_{24}Y^5 |X|+C_{25}Y^4 X^2+C_{26}Y^3 |X^3|\\
&\qquad+C_{27}Y^2 X^4+C_{28}Y|X^5|+C_{29}X^6\\
&+C_{30}Y^7+C_{31}Y^6 |X|+C_{32}Y^5 X^2+C_{33}Y^4 |X^3|\\
&\qquad+C_{34}Y^3 X^4+C_{35}Y^2 |X^5|+C_{36}YX^6+C_{37}|X^7|\\
&\qquad\cdots(c)
\end{aligned}$$

なお、左右眼用の接眼プリズム２Ｌ、２Ｒの最も射出瞳側の屈折面（実施例１～６の面２４Ｌ、２４Ｒ、実施例７～９の面２５Ｌ、２５Ｒ、実施例１０～１１の面２３Ｌ、２３Ｒ）を回転対称非球面にて構成してもよい。この場合は、製作性が向上すると共に、この回転対称非球面を基準面にして他の面の位置出しが容易になる。

また、以上の実施例における左右眼用の光学系を構成する偏心プリズム体２Ｌ、２Ｒとしては、公知の他のタイプの偏心プリズム体を用いてもよい。

さて、次に、本発明による具体的な数値例として、実施例１６～３０の画像表示装置について説明する。

図１６は、実施例１６の画像表示装置を説明するための図であり、図１６（ａ）は両眼の光学系を示す水平断面（Ｙ－Ｚ断面）であり、図１６（ｂ）は右眼用の光学系のみを示す水平断面である。以下、実施例１７～２８については、それぞれ図１７～図２７に、図１６（ａ）と同様の両眼の光学系を示す水平断面図を示す。

何れの実施例の光学系も、前記の実施例１～１５と同様に、両眼の対称面に対して面対称な形状であるので、図１６（ｂ）のような右眼用の光学系の逆光線追跡での構成パラメータのみを後記してある。後記する実施例１６～２８の逆光線追跡での構成パラメータは、図１６（ｂ）に示すように、軸上主光線（光軸）Ｏを、光学系の射出瞳４Ｒの中心を垂直に通り、画像表示素子３中心に至る光線で定義する。そして、逆光線追跡において、瞳４Ｒの中心を偏心光学系の偏心光学面の原点として、軸上主光線Ｏに沿う方向をＺ軸方向とし、瞳４Ｒから光学系の最終面（逆光線追跡では最初の面：入射面。図１６（ｂ）では第４面２４Ｒ）に向かう方向をＺ軸正方向とし、このＺ軸と画像表示素子３中心を含む平面をＹ－Ｚ平面とし、原点を通りＹ－Ｚ平面に直交し、紙面の手前から裏面側に向かう方向をＸ軸正方向とし、Ｘ軸、Ｚ軸と右手直交座標系を構成する軸をＹ軸とする。図１６（ｂ）には、この座標系を図示してある。実施例１７～２８を示す図１７～図２７については、この座標系の図示は省く。

実施例１６～３０では、このＹ－Ｚ平面内で各面の偏心を行っており、また、各回転非対称自由曲面の唯一の対称面をＹ－Ｚ面としている。

偏心面については、上記座標系の原点から、その面の面頂位置の偏心量（Ｘ軸方向、Ｙ軸方向、Ｚ軸方向をそれぞれＸ，Ｙ，Ｚ）と、その面の中心軸（自由曲面については、前記（ａ）式のＺ軸、非球面については、後記（ｄ）式のＺ軸）のＸ軸、Ｙ軸、Ｚ軸それぞれを中心とする傾き角（それぞれα，β，γ（°））

とが与えられている。なお、その場合、αとβの正はそれぞれの軸の正方向に対して反時計回りを、γの正はＺ軸の正方向に対して時計回りを意味する。

また、各実施例の光学系を構成する光学作用面の中、特定の面とそれに続く面が共軸光学系を構成する場合に、面間隔が与えられており、その他、媒質の屈折率、アッベ数が慣用法に従って与えられている。

また、本発明で用いられる自由曲面の面の形状は前記（ａ）式により定義し、その定義式のＺ軸が自由曲面の軸となる。

また、非球面は、以下の定義式で与えられる回転対称非球面である。

$$Z=(Y^2/R)/[1+\{1-(1+K)Y^2/R^2\}^{1/2}] +AY^4+BY^6+CY^8+DY^{10}+\cdots\cdots \quad \cdots (d)$$

ただし、Ｚを光の進行方向を正とした光軸（軸上主光線）とし、Ｙを光軸と垂直な方向にとる。ここで、Ｒは近軸曲率半径、Ｋは円錐定数、Ａ、Ｂ、Ｃ、Ｄ、…はそれぞれ４次、６次、８次、１０次の非球面係数である。この定義式のＺ軸が回転対称非球面の軸となる。

なお、データの記載されていない自由曲面、非球面に関する項は０である。屈折率については、ｄ線（波長５８７．５６ｎｍ）に対するものを表記してある。長さの単位はmmである。

また、自由曲面の他の定義式として、前記の（ｂ）式で与えられるＺｅｒｎｉｋｅ多項式がある。

なお、本発明の実施例では、前記（ａ）式を用いた自由曲面で面形状が表現されているが、上記（ｂ）式、（ｃ）式を用いても同様の作用効果を得られるのは言うまでもない。

さて、図１６（ａ）に戻り、実施例１６の実施例４との大きな違いは、光路振分けプリズム１０の点にある。中央の光路振分けプリズム１０は、両眼の対称面に対して面対称な形状であり、画像表示素子３の観察者と反対側に位置する第１面１１が透過面、その第１面１１の両側で観察者と反対側に位置する右光路用透過面の第３面１４Ｒ、左光路用透過面の第３面１４Ｌ、さらにそれら第４面１４

R、１４Ｌの観察者と反対側に位置する右光路用反射面の第２面１２Ｒと左光路用反射面の第２面１２Ｌの５面からなり、右光路用透過面の第４面１４Ｒ、左光路用透過面の第４面１４Ｌは、それぞれ左光路用反射面の第３面１３Ｌ、右光路用反射面の第３面１３Ｒと同一面からなり、その同一面は透過面と全反射面を兼ねている。そして、第１面１１は両眼の対称面に対して面対称な形状、第４面１４Ｒと１４Ｌ、第２面１２Ｒと１２Ｌは両眼の対称面に対して面対称な形状である。画像表示素子３は、光路振分けプリズム１０の第１面１１に面して、光路振分けプリズム１０の観察者側に配置される。

上記の構成において、左右の光路は両眼の対称面に対して面対称であるので、右眼用の光路を代表的に説明する。共通の１枚の画像表示素子３からの表示光は、まず、光路振分けプリズム１０の第１面１１に入射し、その右光路用反射面の第２面１２Ｒに入射して反射され、次いで左光路用透過面１４Ｌを兼ねる右光路用反射面の第３面１３Ｒに入射して反射され、右光路用透過面１４Ｒを透過して、偏心プリズム体２Ｒに入射する。入射光は第１面２１Ｒを透過してプリズム内に入射し、第２面２２Ｒに臨界角以上の入射角で入射して全反射され、第３面２３Ｒに入射して裏面反射され、第４面２４Ｒに臨界角以下の入射角で入射して屈折されて偏心プリズム体２Ｒから射出し、右眼用の射出瞳４Ｒへ導かれ、観察者の右眼に画像表示素子３の拡大像を投影する。この場合に、画像表示素子３から射出瞳４Ｒへ到る光路中に１回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

図１７の実施例１７は、図１の実施例１と同様であるが、中央の光路振分けミラー１の構成が異なる。この実施例の場合は、両眼の対称面に対して面対称な形状の右光路用反射面１Ｒと左光路用反射面１Ｌはそれぞれレンズ８Ｒ、８Ｌの裏面にコートされた裏面鏡からなる。その他は同様である。

この構成において、左右の光路は両眼の対称面に対して面対称であるので、右眼用の光路を代表的に説明する。共通の１枚の画像表示素子３からの表示光は、まず、光路振分けミラー１の右光路用レンズ８Ｒの入射面１１Ｌから入射し、反

射面１Ｒで反射され、再び入射面１１Ｌから射出し、偏心プリズム体２Ｒに入射する。入射光は第１面２１Ｒを透過してプリズム内に入射し、第２面２２Ｒに臨界角以上の入射角で入射して全反射され、第３面２３Ｒに入射して裏面反射され、第４面２４Ｒに臨界角以下の入射角で入射して屈折されて偏心プリズム体２Ｒから射出し、右眼用の射出瞳４Ｒへ導かれ、観察者の右眼に画像表示素子３の拡大像を投影する。なお、画像表示素子３から射出瞳４Ｒへ到る光路中には中間像は結像されない。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

図１８の実施例１８は、図４の実施例４と同様である。

図１９の実施例１９は、図５の実施例５と同様である。

図２０の実施例２０は、図６の実施例６と同様である。

図２１の実施例２１の実施例６との大きな違いは、光路振分けプリズム１０の点にある。中央の光路振分けプリズム１０は、両眼の対称面に対して面対称な形状であり、画像表示素子３の観察者側に位置する第１面１１が透過面、その第１面１１に面していて観察者に面する反射面の右光路用反射面の第２面１２Ｒと左光路用反射面の第２面１２Ｌ、第１面１１の観察者側両側に配置された右光路用反射面の第３面１３Ｒと左光路用反射面の第３面１３Ｌ、第３面１３Ｒ、１３Ｌと第２面１２Ｒ、１２Ｌの間の両側に配置された左光路用透過面の第４面１４Ｌ、右光路用透過面の第４面１４Ｒの７面からなる。第１面１１は両眼の対称面に対して面対称な形状、第２面１２Ｒと１２Ｌ、第３面１３Ｒと１３Ｌ、第４面１４Ｌと１４Ｒは両眼の対称面に対して面対称な形状である。画像表示素子３は、光路振分けプリズム１０の第１面１１に面して、光路振分けプリズム１０の観察者とは反対側に配置される。

上記の構成において、左右の光路は両眼の対称面に対して面対称であるので、右眼用の光路を代表的に説明する。共通の１枚の画像表示素子３からの表示光は、まず、光路振分けプリズム１０の第１面１１に入射し、その右光路用反射面の第２面１２Ｒに入射して反射され、次いで第３面１３Ｒに入射して反射され、右光路用透過面１４Ｒを透過して、偏心プリズム体２Ｒに入射する。入射光は第１

面２１Ｒを透過してプリズム内に入射し、第２面２２Ｒに臨界角以上の入射角で入射して全反射され、第３面２３Ｒに入射して裏面反射され、第４面２４Ｒに臨界角以下の入射角で入射して屈折されて偏心プリズム体２Ｒから射出し、右眼用の射出瞳４Ｒへ導かれ、観察者の右眼に画像表示素子３の拡大像を投影する。この場合に、画像表示素子３から射出瞳４Ｒへ到る光路中に１回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

図２２の実施例２２は、図２１の実施例２１と同様であるが、接眼光学系を構成する右眼用、左眼用の偏心プリズム体２Ｒ、２Ｌの射出面２４Ｒ、２４Ｌと右眼用、左眼用の射出瞳４Ｒ、４Ｌの間にそれぞれ接眼レンズ９Ｒと９Ｌを配置した点で異なる。

図２３の実施例２３は、図２の実施例２と同様である。

図２４の実施例２４は、図２の実施例２と同様であるが、負レンズ５を接合レンズで構成している点で異なる。

図２５の実施例２５の実施例１との大きな違いは、中央の光路振分けミラー１が、両眼の対称面に対して面対称な形状の右光路用反射面１Ｒと左光路用反射面１Ｌに加えて、それらに面する第２の右光路用反射面１Ｒ’と第２の左光路用反射面１Ｌ’との４面の反射面からなり、第２の反射面１Ｒ’と１Ｌ’は両眼の対称面に対して面対称な形状であり、かつ、画像表示素子３は、光路振分けミラー１の観察者と反対側に配置される点にある。

上記の構成において、左右の光路は両眼の対称面に対して面対称であるので、右眼用の光路を代表的に説明する。共通の１枚の画像表示素子３からの表示光は、まず、光路振分けミラー１の右光路用反射面１Ｒに入射して反射され、次いで第２の右光路用反射面１Ｒ’に入射して反射され、偏心プリズム体２Ｒに入射する。入射光は第１面２１Ｒを透過してプリズム内に入射し、第２面２２Ｒに臨界角以上の入射角で入射して全反射され、第３面２３Ｒに入射して裏面反射され、第４面２４Ｒに臨界角以下の入射角で入射して屈折されて偏心プリズム体２Ｒから射出し、右眼用の射出瞳４Ｒへ導かれ、観察者の右眼に画像表示素子３の拡大

像を投影する。この場合に、画像表示素子３から射出瞳４Ｒへ到る光路中に１回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面を挟んで、右眼用の光路と面対称な関係になる。

図２６の実施例２６は、図１１の実施例１１と同様である。

図２７の実施例２７は、図７の実施例７と同様である。ただし、右眼用、左眼用の接眼光学系を構成する偏心プリズム体２Ｌ、２Ｒの第２面２２Ｌ、２２Ｒと第４面２４Ｌ、２４Ｒはそれぞれ同一の反射面からなっている。

図２８の実施例２８は、図１２の実施例１２と同様である。

図２９に、本発明による実施例２９～３０の画像表示装置の光路図を示す。図２９において、画像表示素子を構成する画像表示素子を符号３で、右眼用の射出瞳を４Ｒで、左眼用の射出瞳を４Ｌで示し、また、右眼用の光学系で右眼前に配置する偏心プリズム体を２Ｒ、左眼用の光学系で左眼前に配置する偏心プリズム体を２Ｌで示す。さらに、両眼の中央に配置する偏心プリズム体からなる光路振分けプリズムを１０で示す。これらの偏心プリズム体２Ｒ、２Ｌ、１０は屈折率が１より大きい透明媒体からなっている。また、下記の説明において、反射面と説明している面は、全反射面以外は偏心プリズム体の対象の面にミラーコートを施してミラー面としたものである。

この実施例２９～３０は、図２９に水平断面（Ｙ－Ｚ断面）を示すような構成になっており、まず、右眼用の光路で説明する。中央の三角柱状の光路振分けプリズム１０は、両眼の対称面（右眼用射出瞳４Ｒと左眼用射出瞳４Ｌの中心間を結んだ線分の中心を通りその線分に垂直な平面）２０に対して面対称な形状であり、画像表示素子３の観察者側に位置する第１面１１が透過面、その第１面１１の両側で観察者側に位置する全反射面として作用する右光路用反射面の第２面１２Ｒと左光路用反射面の第２面１２Ｌ、右光路用反射面の第２面１２Ｒと同一面の左光路用透過面１３Ｌ、左光路用反射面の第２面１２Ｌと同一面の右光路用透過面１３Ｒの３面からなる。第１面１１は両眼の対称面２０に対して面対称な形状、第２面１２Ｒ（１３Ｌ）と１２Ｌ（１３Ｒ）は両眼の対称面２０に対して面対称な形状である。画像表示素子３は、光路振分けプリズム１０の第１面１１に

面して、光路振分けプリズム１０の観察者とは反対側に配置される。

右眼用の光学系を構成する偏心プリズム体２Ｒと左眼用の光学系を構成する偏心プリズム体２Ｌとは同一形状のもので、両眼の対称面２０に対して面対称に配置され、それぞれ光線が通る順番で、第１面２１Ｒ（２１Ｌ）、第２面２２Ｒ（２２Ｌ）、第３面２３Ｒ（２３Ｌ）、第４面２４Ｒ（２４Ｌ）から構成されており、第２面２２Ｒ（２２Ｌ）と第４面２４Ｒ（２４Ｌ）は同一面からなり、その同一面は全反射面と透過面を兼ねている。

上記の構成において、左右の光路は両眼の対称面２０に対して面対称であるので、右眼用の光路を代表的に説明する。共通の１枚の画像表示素子３からの表示光は、まず、光路振分けプリズム１０の第１面１１に入射し、その右光路用反射面の第２面１２Ｒに入射して全反射され、右光路用透過面１３Ｒ（１２Ｌ）を透過して、偏心プリズム体２Ｒに入射する。入射光は第１面２１Ｒを透過してプリズム内に入射し、第２面２２Ｒに臨界角以上の入射角で入射して全反射され、第３面２３Ｒに入射して裏面反射され、第４面２４Ｒに臨界角以下の入射角で入射して屈折されて偏心プリズム体２Ｒから射出し、右眼用の射出瞳４Ｒへ導かれ、観察者の右眼に画像表示素子３の拡大像を投影する。この場合に、画像表示素子３から射出瞳４Ｒへ到る光路中に１回中間像が結像される。左眼用の光路は、右眼用の光学系の配置と同様、両眼の対称面２０を挟んで、右眼用の光路と面対称な関係になる。

以上のような構成であるので、左右の光路何れにおいても、画像表示素子３からの表示光は、３回の反射を経て眼球に導かれるので、左右共相互に鏡像でなく同じ配置の画像を見ることができ、しかも、偏心あるいは光軸に対して傾けて配置された少なくとも１面が正パワーを有する反射面及び透過面を経て画像表示素子３の画像が投影されるので、像面湾曲、色収差等の諸収差が良好に補正された画像を投影することができる。

さらに、左右何れの光路も大部分、屈折率が１より大きい透明媒体で満たされた偏心プリズム体１０、２Ｒ、２Ｌ中を通過し、かつ、その中で光路が折り曲げられるので、接眼光学系全体をコンパクトなものとすることができる。

また、偏心プリズム体２Ｒ、２Ｌは面対称な位置に配置されるが、その形状は同一なものである、同じ形状の２つの偏心プリズム体２Ｒ、２Ｌを用意し、中央の偏心プリズム体１０に対して面対称な位置に配置すればよい。

以上のような光学系には、視野角特性の広い画像表示素子３を使うことが前提となる。そのため、画像表示素子３には、自家発光タイプの有機ＥＬ（図４０参照）を用いるのが望ましい。また、透過型ＬＣＤ（液晶表示素子）を用いる場合には、ＬＣＤとバックライトの間にＤＯＥ（回折光学素子）を入れて、±１次光で照明すること、あるいは、視野角が大きくなるような散乱フィルムを使うことで、視野角特性を広くしたＬＣＤを使うことが望ましい（実施例１～３０においても同様である。）。

ところで、図３０に示すように、画像表示素子３の表示画像を右眼用光路と左眼用光路とに振分ける光路振分けプリズム１０の第２面１２Ｒと１２Ｌの表示光の反射時における角度α（本発明の画像表示装置では、右眼の光路と左眼の光路は面対称な関係にあるので、図３０では、簡単のため、右眼用光路のみを示してある。）は、

$$33^\circ \leqq \alpha \leqq 70^\circ \quad \cdots (1)$$

となる条件を満たすことが望ましい。この条件式の下限の３３°を下回る場合は、光線が第２面１２Ｒと１２Ｌで反射せずに透過してしまい、像を形成しない。上限の７０°を上回る場合は、この光学系の構成で前述の光路を通ることは難しく、像を形成しなくなる。

さらに好ましくは、

$$40^\circ \leqq \alpha \leqq 60^\circ \quad \cdots (1-1)$$

となる条件を満たすことが望ましい。下限と上限の意味については、上記の条件式（１）と同様である。

次に、図３０に示すように、右眼用射出瞳４Ｒと左眼用射出瞳４Ｌの中心間を結んだ線分の中心を通りその線分に垂直な平面２０（両眼の対称面）と、光路振分けプリズム１０の第２面１２Ｒに右眼用光路の光軸が入射する点における第２面１２Ｒの接平面１５とがなす角β、及び、平面２０と光路振分けプリズム１０

の第２面１２Ｌに左眼用光路の光軸が入射する点における第２面１２Ｌの接平面とがなす角βは、

１３°≦β≦２４°　　　　　　　　　　　　　　　　　・・・（２）

となる条件を満たすことが望ましい。この条件式の下限の１３°を下回る場合は、一部の光線が反射後の第３面１３Ｒで透過せずに反射したり、偏心プリズム体２Ｒの第２面２２Ｒを反射せずに透過してしまい、前述の光路を通ることは難しく、像を形成しなくなる。上限の２４°を上回る場合は、一部の光線が第２面１２Ｒで反射せずに透過してしまい、前述の光路を通ることは難しく、像を形成しなくなる。

さらに好ましくは、

１５°≦β≦２２°　　　　　　　　　　　　　　　・・・（２－１）

となる条件を満たすことが望ましい。下限と上限の意味については、上記の条件式（２）と同様である。

さらに好ましくは、

１７°≦β≦２０°　　　　　　　　　　　　　　　・・・（２－２）

となる条件を満たすことが望ましい。下限と上限の意味については、上記の条件式（２）と同様である。

次に、瞳側から逆光線追跡した場合に、右眼用射出瞳４Ｒ中心を通る右側最大画角の光線と右眼用の偏心プリズム体２Ｒの第４面２４Ｒとが交わる点と、左眼用射出瞳４Ｌ中心を通る左側最大画角の光線と左眼用の偏心プリズム体２Ｌの第４面２４Ｌとが交わる点との間隔を、図３１に示すように、横幅Ｌとし、また、左右の射出瞳中心を通る全画角内の光線束の中、右眼ＥＲ用の偏心プリズム体２Ｒあるいは左眼ＥＬ用の偏心プリズム体２Ｌの第４面２４Ｒ、２４Ｌを透過あるいは反射する点の中で最も左右の射出瞳側に近い点と、画像表示素子３の表示面とのその表示面に垂直な方向の距離を奥行Ｄとした場合、この横幅Ｌと奥行Ｄとの比Ｄ／Ｌが、

０．３≦Ｄ／Ｌ≦０．５　　　　　　　　　　　　　　　・・・（３）

となる条件を満たすことが望ましい。下限の０．３を下回る場合は、広い画角が

取れなくなり、画面が小さくなってしまう。上限の０．５を上回る場合は、奥行が大きくなり、光学系が大型化してしまう。

さらに好ましくは、

０．３５≦Ｄ／Ｌ≦０．４５ ・・・（３－１）

となる条件を満たすことが望ましい。下限と上限の意味については、上記の条件式（３）と同様である。

上記のように、実施例２９、３０では、右眼用の光学系光路と左眼用の光学系光路は面対称な関係にあるので、図３２、図３３にそれぞれ上記実施例２９、３０の右眼用の光学系のみを示す水平断面図を示す。左眼用の光学系については、両眼の対称面２０（図２９）に対して、面対称の関係となるように、左眼用の光学系の面を配置すればよい。

以下に上記実施例１６～３０の逆光線追跡での右眼用光学系の構成パラメータを示す。これらの実施例は、観察光学系とした場合に、実施例１６～２１、２３～２８の観察画角は、水平半画角１０°、垂直半画角７．５°、実施例２２の観察画角は、水平半画角１２°、垂直半画角９．１°であり、実施例２９の観察画角は、水平半画角７°、垂直半画角５．２６°であり、実施例３０の観察画角は、水平半画角７．５°、垂直半画角５．６４°である。また、実施例１６～２８において、画像表示素子の大きさは、８．９×６．７ｍｍであり、実施例２９においては、８．９４×６．７１ｍｍであり、実施例３０においては、８．９４×６．７１ｍｍである。瞳径は、実施例１６～３０全てにおいて、４ｍｍである。なお、実施例２９は、観察光学系とした場合に、焦点距離３６ｍｍに相当し、実施例３０は、焦点距離３４ｍｍに相当する。

なお、以下の表中の“ＦＦＳ”は自由曲面、“ＡＳＳ”は非球面、“ＲＥ”は反射面をそれぞれ示す。

Example １６

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.

Object plane	∞	-1000.00		
1	∞ (Stop)			
2	ＡＳＳ①	(1)	1.5254	56.2
3	ＦＦＳ①（ＲＥ）	(2)	1.5254	56.2
4	ＡＳＳ①（ＲＥ）	(1)	1.5254	56.2
5	ＦＦＳ②	(3)		
6	ＦＦＳ③	(4)	1.5254	56.2
7	ＦＦＳ④（ＲＥ）	(5)	1.5254	56.2
8	ＦＦＳ⑤（ＲＥ）	(6)	1.5254	56.2
9	∞	(7)		
Image plane	∞	(8)		

ＡＳＳ①

R -61.00

K 0.0000

A -2.8485×10^{-6}

B 8.9070×10^{-9}

ＦＦＳ①

C_4 -1.2212×10^{-2} C_6 -1.2499×10^{-2} C_8 -7.2115×10^{-6}

C_{10} 3.6893×10^{-5} C_{11} -2.8593×10^{-6} C_{13} -3.0073×10^{-6}

C_{15} -3.4462×10^{-6} C_{17} -1.6344×10^{-9} C_{19} -4.1364×10^{-8}

C_{21} -2.0345×10^{-8}

ＦＦＳ②

C_4 1.0330×10^{-2} C_6 -2.2053×10^{-2} C_8 -8.5243×10^{-5}

C_{10} -1.3497×10^{-3} C_{11} 1.1148×10^{-4} C_{13} -2.6040×10^{-4}

C_{15} 3.9230×10^{-4}

ＦＦＳ③

C_4 -8.5360×10^{-3} C_6 -8.8071×10^{-3} C_8 7.1801×10^{-5}

C_{10} 7.6086×10^{-5} C_{11} 6.3213×10^{-7} C_{13} 8.2333×10^{-6}

C_{15} 1.9455×10^{-6}

FFS④

C_4 8.5360×10^{-3} C_6 8.8071×10^{-3} C_8 -7.1801×10^{-5}

C_{10} -7.6086×10^{-5} C_{11} -6.3213×10^{-7} C_{13} -8.2333×10^{-6}

C_{15} -1.9455×10^{-6}

FFS⑤

C_4 1.2329×10^{-2} C_6 6.7124×10^{-3} C_8 -3.9501×10^{-5}

C_{10} -1.3809×10^{-4} C_{11} -1.6628×10^{-6} C_{13} 3.6302×10^{-6}

C_{15} -3.8832×10^{-6}

Displacement and tilt(1)

X 0.00 Y 9.84 Z 32.73

α -0.88 β 0.00 γ 0.00

Displacement and tilt(2)

X 0.00 Y -0.48 Z 39.28

α -30.61 β 0.00 γ 0.00

Displacement and tilt(3)

X 0.00 Y 16.17 Z 37.03

α 35.52 β 0.00 γ 0.00

Displacement and tilt(4)

X 0.00 Y 19.39 Z 46.79

α -91.71 β 0.00 γ 0.00

Displacement and tilt(5)

X 0.00 Y 44.61 Z 46.79

α -88.29 β 0.00 γ 0.00

Displacement and tilt(6)

X 0.00 Y 22.62 Z 55.56

α 136.79 β 0.00 γ 0.00

Displacement and tilt(7)

X 0.00 Y 32.00 Z 33.76

α -180.00 β 0.00 γ 0.00

Displacement and tilt(8)

X 0.00 Y 32.00 Z 29.64

α -180.00 β 0.00 γ 0.00

Example 17

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	ASS①		(1)	1.5254	56.2
3	FFS① (RE)		(2)	1.5254	56.2
4	ASS① (RE)		(1)	1.5254	56.2
5	FFS②		(3)		
6	FFS③		(4)	1.5254	56.2
7	FFS④ (RE)		(5)	1.5254	56.2
8	FFS③		(4)		
Image plane	∞		(6)		

ASS①

R -95.45

K 0.0000

A -6.5740×10^{-8}

B 1.3849×10^{-9}

FFS①

C_4 -1.0306×10^{-2}	C_6 -1.0412×10^{-2}	C_8 2.0096×10^{-5}
C_{10} 2.8787×10^{-5}	C_{11} -7.7967×10^{-7}	C_{13} -2.3996×10^{-6}
C_{15} -2.6208×10^{-6}	C_{17} -6.0108×10^{-8}	C_{19} 1.1907×10^{-8}
C_{21} 1.4876×10^{-8}		

FFS②

C_4 -7.5538×10^{-3}	C_6 6.2696×10^{-4}	C_8 1.3858×10^{-3}
C_{10} 2.0287×10^{-3}	C_{11} 8.0303×10^{-5}	C_{13} -1.5350×10^{-4}
C_{15} -6.5070×10^{-5}		

FFS③

C_4 -7.6923×10^{-2}	C_6 -9.3217×10^{-3}	C_8 3.8760×10^{-3}
C_{10} -9.4736×10^{-4}	C_{11} -7.2844×10^{-4}	C_{13} 6.5675×10^{-4}
C_{15} -4.9359×10^{-5}		

FFS④

C_4 -1.1587×10^{-2}	C_6 1.1772×10^{-2}	C_8 1.0849×10^{-3}
C_{10} -1.8206×10^{-4}	C_{11} -5.4651×10^{-4}	C_{13} 1.7195×10^{-4}
C_{15} -1.3202×10^{-5}		

Displacement and tilt(1)

X	0.00	Y	9.05	Z	39.11
α	10.70	β	0.00	γ	0.00

Displacement and tilt(2)

X	0.00	Y	0.24	Z	48.07
α	-21.35	β	0.00	γ	0.00

Displacement and tilt(3)

X	0.00	Y	19.03	Z	43.57
α	92.98	β	0.00	γ	0.00

Displacement and tilt(4)

X	0.00	Y	35.65	Z	58.02

α	-145.94	β	0.00	γ	0.00

Displacement and tilt(5)

X	0.00	Y	39.28	Z	61.80
α	-147.29	β	0.00	γ	0.00

Displacement and tilt(6)

X	0.00	Y	32.00	Z	38.00
α	0.00	β	0.00	γ	0.00

Example 18

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	ASS①		(1)	1.5254	56.2
3	FFS① (RE)		(2)	1.5254	56.2
4	ASS① (RE)		(1)	1.5254	56.2
5	FFS②		(3)		
6	FFS③		(4)	1.5254	56.2
7	FFS④ (RE)		(5)	1.5254	56.2
8	FFS⑤		(6)		
Image plane	∞		(7)		

ASS①

R	-99.17
K	0.0000
A	-5.1344×10^{-6}
B	5.4560×10^{-9}

FFS①

C_4	-1.3402×10^{-2}	C_6	-1.1018×10^{-2}	C_8	2.9828×10^{-6}
C_{10}	-4.6829×10^{-6}	C_{11}	-2.4079×10^{-6}	C_{13}	-3.1115×10^{-6}
C_{15}	-2.2505×10^{-6}	C_{17}	1.0452×10^{-7}	C_{19}	1.1084×10^{-7}
C_{21}	2.6833×10^{-8}				

FFS②

C_4	-1.9489×10^{-2}	C_6	-3.8808×10^{-3}	C_8	4.8522×10^{-3}
C_{10}	4.8858×10^{-3}	C_{11}	1.8575×10^{-4}	C_{13}	-7.7300×10^{-4}
C_{15}	-6.0291×10^{-4}				

FFS③

C_4	-8.6443×10^{-2}	C_6	-3.9460×10^{-2}	C_8	8.0248×10^{-3}
C_{10}	9.1640×10^{-3}	C_{11}	-6.2318×10^{-5}	C_{13}	1.4493×10^{-3}
C_{15}	1.6706×10^{-3}				

FFS④

C_4	1.9984×10^{-2}	C_6	1.7719×10^{-2}	C_8	2.2720×10^{-4}
C_{10}	2.2345×10^{-4}	C_{11}	6.1407×10^{-6}	C_{13}	2.3412×10^{-5}
C_{15}	-1.4916×10^{-6}				

FFS⑤

C_4	-1.0029×10^{-2}	C_6	4.6836×10^{-3}

Displacement and tilt(1)

X	0.00	Y	12.74	Z	36.00
α	2.52	β	0.00	γ	0.00

Displacement and tilt(2)

X	0.00	Y	-0.37	Z	45.03
α	-28.87	β	0.00	γ	0.00

Displacement and tilt(3)

X	0.00	Y	20.71	Z	40.51
α	74.60	β	0.00	γ	0.00

Displacement and tilt(4)

X	0.00	Y	22.61	Z	41.95
α	-113.38	β	0.00	γ	0.00

Displacement and tilt(5)

X	0.00	Y	38.54	Z	52.07
α	-144.30	β	0.00	γ	0.00

Displacement and tilt(6)

X	0.00	Y	32.00	Z	36.77
α	0.00	β	0.00	γ	0.00

Displacement and tilt(7)

X	0.00	Y	32.00	Z	30.00
α	0.00	β	0.00	γ	0.00

Example 1 9

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	ASS①		(1)	1.5254	56.2
3	FFS① (RE)		(2)	1.5254	56.2
4	ASS① (RE)		(1)	1.5254	56.2
5	FFS②		(3)		
6	FFS③		(4)	1.5254	56.2
7	FFS④ (RE)		(5)	1.5254	56.2
8	FFS⑤		(6)		
Image plane	∞		(7)		

ASS①

R 371.46

K 0.0000

A -8.4688×10^{-7}

B 2.9089×10^{-10}

FFS①

C_4	-6.3820×10^{-3}	C_6	-8.9287×10^{-3}	C_8	-7.5189×10^{-5}
C_{10}	-2.7485×10^{-6}	C_{11}	-5.1745×10^{-6}	C_{13}	-6.0033×10^{-7}
C_{15}	2.8823×10^{-6}	C_{17}	3.2184×10^{-7}	C_{19}	8.6382×10^{-8}
C_{21}	-1.5498×10^{-8}				

FFS②

C_4	-4.0226×10^{-2}	C_6	-3.3297×10^{-2}	C_8	2.4201×10^{-3}
C_{10}	6.0781×10^{-3}	C_{11}	7.4789×10^{-4}	C_{13}	-3.2635×10^{-4}
C_{15}	2.1572×10^{-4}				

FFS③

C_4	-2.0127×10^{-2}	C_6	-1.4009×10^{-2}	C_8	-1.3093×10^{-3}
C_{10}	-1.0645×10^{-4}	C_{11}	-2.3099×10^{-4}	C_{13}	-2.8818×10^{-5}
C_{15}	-1.4532×10^{-6}				

FFS④

C_4	2.0127×10^{-2}	C_6	1.4009×10^{-2}	C_8	1.3093×10^{-3}
C_{10}	1.0645×10^{-4}	C_{11}	2.3099×10^{-4}	C_{13}	2.8818×10^{-5}
C_{15}	1.4532×10^{-6}				

FFS⑤

C_4	2.3952×10^{-1}	C_6	6.3371×10^{-4}

Displacement and tilt(1)

X	0.00	Y	20.12	Z	35.02
α	6.83	β	0.00	γ	0.00

Displacement and tilt(2)

X	0.00	Y	0.52	Z	47.68
α	-27.07	β	0.00	γ	0.00

Displacement and tilt(3)

X	0.00	Y	27.52	Z	37.59
α	76.08	β	0.00	γ	0.00

Displacement and tilt(4)

X	0.00	Y	29.00	Z	40.96
α	-118.18	β	0.00	γ	0.00

Displacement and tilt(5)

X	0.00	Y	35.00	Z	40.96
α	-61.82	β	0.00	γ	0.00

Displacement and tilt(6)

X	0.00	Y	32.00	Z	50.73
α	-180.00	β	0.00	γ	0.00

Displacement and tilt(7)

X	0.00	Y	32.00	Z	58.00
α	-180.00	β	0.00	γ	0.00

Example 20

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	ASS①		(1)	1.5254	56.2
3	FFS① (RE)		(2)	1.5254	56.2
4	ASS① (RE)		(1)	1.5254	56.2
5	FFS②		(3)		

6	FFS③	(4)	1.5254	56.2
7	FFS④ (RE)	(5)	1.5254	56.2
8	FFS⑤ (RE)	(6)	1.5254	56.2
9	FFS⑥	(7)		
Image plane	∞	(8)		

ASS①

R -78.87

K 0.0000

A 6.3888×10^{-6}

B -6.7614×10^{-9}

FFS①

C_4 -1.3820×10^{-2} C_6 -1.2744×10^{-2} C_8 -5.9146×10^{-5}

C_{10} -8.6079×10^{-5} C_{11} -1.5009×10^{-6} C_{13} -3.9389×10^{-6}

C_{15} -3.9837×10^{-6} C_{17} 9.5456×10^{-8} C_{19} 2.5646×10^{-7}

C_{21} 8.4257×10^{-8}

FFS②

C_4 -4.8112×10^{-2} C_6 2.2437×10^{-2} C_8 1.2629×10^{-2}

C_{10} -1.4147×10^{-3} C_{11} 1.1201×10^{-3} C_{13} -4.2802×10^{-3}

C_{15} -1.8265×10^{-5}

FFS③

C_4 -2.4894×10^{-2} C_6 1.7719×10^{-3} C_8 1.3030×10^{-2}

C_{10} 8.7223×10^{-3} C_{11} -2.5693×10^{-3} C_{13} 2.0937×10^{-3}

C_{15} -1.7955×10^{-4}

FFS④

C_4 1.4510×10^{-2} C_6 1.4974×10^{-2} C_8 6.3447×10^{-5}

C_{10} -3.3021×10^{-5} C_{11} 6.7340×10^{-6} C_{13} 1.3268×10^{-5}

C_{15} 5.6476×10^{-6}

FFS⑤

C_4 -5.0177×10^{-3} C_6 4.2398×10^{-3} C_{11} 1.3297×10^{-5}

C_{13} 1.7182×10^{-5} C_{15} 7.8122×10^{-6}

FFS⑥

C_4 6.6144×10^{-2} C_6 3.1372×10^{-2} C_{11} 5.4070×10^{-4}

C_{13} -2.1336×10^{-4} C_{15} -4.3706×10^{-4}

Displacement and tilt(1)

X 0.00 Y 13.06 Z 30.44

α 4.48 β 0.00 γ 0.00

Displacement and tilt(2)

X 0.00 Y -0.13 Z 38.51

α -29.74 β 0.00 γ 0.00

Displacement and tilt(3)

X 0.00 Y 17.85 Z 32.43

α 74.33 β 0.00 γ 0.00

Displacement and tilt(4)

X 0.00 Y 19.17 Z 33.07

α -102.30 β 0.00 γ 0.00

Displacement and tilt(5)

X 0.00 Y 44.66 Z 43.01

α -133.87 β 0.00 γ 0.00

Displacement and tilt(6)

X 0.00 Y 32.00 Z 30.30

α -180.00 β 0.00 γ 0.00

Displacement and tilt(7)

X 0.00 Y 32.00 Z 48.57

α 0.00 β 0.00 γ 0.00

Displacement and tilt(8)

X	0.00	Y	32.00	Z	53.57
α	0.00	β	0.00	γ	0.00

Example 21

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)		(1)		
2	ASS①		(2)	1.5254	56.2
3	FFS① (RE)		(3)	1.5254	56.2
4	ASS① (RE)		(2)	1.5254	56.2
5	FFS②		(4)		
6	FFS③		(5)	1.5254	56.2
7	FFS④ (RE)		(6)	1.5254	56.2
8	FFS⑤ (RE)		(7)	1.5254	56.2
9	FFS⑥		(8)		
Image plane	∞		(9)		

ASS①

R	-93.13
K	0.0000
A	-7.3153×10^{-6}
B	1.0465×10^{-8}

FFS①

C_4	-1.2530×10^{-2}	C_6	-1.0935×10^{-2}	C_8	4.3572×10^{-5}
C_{10}	5.6790×10^{-5}	C_{11}	-4.6759×10^{-6}	C_{13}	-5.7024×10^{-6}
C_{15}	-2.5865×10^{-6}	C_{17}	5.1708×10^{-8}	C_{19}	4.7739×10^{-8}

C_{21} 4.8274×10^{-8}

FFS②

C_4	2.1276×10^{-2}	C_6	-1.3001×10^{-2}	C_8	1.2698×10^{-2}
C_{10}	-4.0940×10^{-3}	C_{11}	6.8259×10^{-4}	C_{13}	-1.1193×10^{-3}
C_{15}	-4.9525×10^{-5}				

FFS③

C_4	-7.7818×10^{-2}	C_6	-1.3978×10^{-2}	C_8	8.2943×10^{-3}
C_{10}	-3.6125×10^{-3}	C_{11}	-2.1473×10^{-3}	C_{13}	1.6422×10^{-3}
C_{15}	2.1472×10^{-4}				

FFS④

C_4	1.7708×10^{-2}	C_6	9.8479×10^{-3}	C_8	4.2747×10^{-5}
C_{10}	1.4710×10^{-6}	C_{11}	6.0476×10^{-6}	C_{13}	9.5455×10^{-6}
C_{15}	7.9647×10^{-6}				

FFS⑤

C_4	-3.2083×10^{-3}	C_6	-1.1682×10^{-2}	C_8	-3.8379×10^{-4}
C_{10}	-4.7983×10^{-4}	C_{11}	3.2203×10^{-5}	C_{13}	2.4146×10^{-5}
C_{15}	1.5623×10^{-5}				

FFS⑥

C_4	-1.2690×10^{-2}	C_6	1.2046×10^{-2}

Displacement and tilt(1)

X	0.00	Y	0.00	Z	0.00
α	0.00	β	0.00	γ	0.00

Displacement and tilt(2)

X	0.00	Y	11.12	Z	31.05
α	6.41	β	0.00	γ	0.00

Displacement and tilt(3)

X	0.00	Y	-0.11	Z	39.90
α	-26.24	β	0.00	γ	0.00

Displacement and tilt(4)

X	0.00	Y	19.37	Z	34.98
α	52.37	β	0.00	γ	0.00

Displacement and tilt(5)

X	0.00	Y	19.70	Z	35.09
α	-124.03	β	0.00	γ	0.00

Displacement and tilt(6)

X	0.00	Y	41.67	Z	44.93
α	-137.82	β	0.00	γ	0.00

Displacement and tilt(7)

X	0.00	Y	36.67	Z	30.00
α	-176.69	β	0.00	γ	0.00

Displacement and tilt(8)

X	0.00	Y	32.00	Z	48.79
α	0.00	β	0.00	γ	0.00

Displacement and tilt(9)

X	0.00	Y	32.00	Z	51.01
α	0.00	β	0.00	γ	0.00

Example 2 2

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)		(1)		
2	∞		(2)	1.4924	107.9
3	ASS①		(3)		
4	ASS②		(4)	1.5254	56.2

5	FFS① (RE)	(5)	1.5254	56.2
6	ASS② (RE)	(4)	1.5254	56.2
7	FFS②	(6)		
8	FFS③	(7)	1.5254	56.2
9	FFS④ (RE)	(8)	1.5254	56.2
10	FFS⑤ (RE)	(9)	1.5254	56.2
11	FFS⑥	(10)		
Image plane	∞	(11)		

ASS①

R -31.17

K 0.0000

A -2.3392×10^{-6}

B 1.4417×10^{-8}

ASS②

R -104.32

K 0.0000

A -1.1160×10^{-5}

B 1.3866×10^{-8}

FFS①

C_4 -1.1076×10^{-2} C_6 -9.7026×10^{-3} C_8 1.2453×10^{-4}

C_{10} 8.6331×10^{-5}

FFS②

C_4 -2.6908×10^{-2} C_6 -2.2030×10^{-2} C_8 3.0544×10^{-3}

C_{10} -2.0443×10^{-3}

FFS③

C_4 -4.7273×10^{-2} C_6 -2.9318×10^{-2} C_8 4.8533×10^{-4}

C_{10} -2.1511×10^{-3}

FFS④

C_4 1.3337×10^{-2} C_6 7.7917×10^{-3} C_8 5.2903×10^{-6}

C_{10} 3.2236×10^{-5}

FFS⑤

C_4 -7.4443×10^{-3} C_6 -1.1004×10^{-2} C_8 -3.4435×10^{-4}

C_{10} -2.7416×10^{-4}

FFS⑥

C_4 8.1792×10^{-3} C_6 7.4722×10^{-3}

Displacement and tilt(1)

X 0.00 Y 0.00 Z 0.00

α 0.00 β 0.00 γ 0.00

Displacement and tilt(2)

X 0.00 Y 0.00 Z 25.00

α 0.00 β 0.00 γ 0.00

Displacement and tilt(3)

X 0.00 Y 0.00 Z 29.43

α 0.00 β 0.00 γ 0.00

Displacement and tilt(4)

X 0.00 Y 10.49 Z 30.94

α 6.19 β 0.00 γ 0.00

Displacement and tilt(5)

X 0.00 Y -0.10 Z 40.19

α -24.76 β 0.00 γ 0.00

Displacement and tilt(6)

X 0.00 Y 18.51 Z 35.34

α 55.35 β 0.00 γ 0.00

Displacement and tilt(7)

X 0.00 Y 19.05 Z 35.60

α -111.46 β 0.00 γ 0.00

Displacement and tilt(8)

X 0.00 Y 41.39 Z 45.63

α -142.01 β 0.00 γ 0.00

Displacement and tilt(9)

X 0.00 Y 38.56 Z 29.81

α 177.05 β 0.00 γ 0.00

Displacement and tilt(10)

X 0.00 Y 32.00 Z 49.26

α 0.00 β 0.00 γ 0.00

Displacement and tilt(11)

X 0.00 Y 32.00 Z 51.37

α 0.00 β 0.00 γ 0.00

Example 2 3

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	ASS①		(1)	1.5254	56.2
3	FFS① (RE)		(2)	1.5254	56.2
4	ASS① (RE)		(1)	1.5254	56.2
5	FFS②		(3)		
6	FFS③ (RE)		(4)		
7	9.36		(5)	1.5254	56.2
8	ASS②		(6)		
Image	∞		(7)		

plane

ASS①

R	-112.57
K	0.0000
A	1.2804×10^{-7}
B	1.9023×10^{-9}

ASS②

R	17.18
K	0.0000
A	-1.1585×10^{-4}
B	4.5485×10^{-6}

FFS①

C_4	-1.0758×10^{-2}	C_6	-1.0721×10^{-2}	C_8	7.6154×10^{-5}
C_{10}	-1.9106×10^{-5}	C_{11}	4.9749×10^{-6}	C_{13}	-5.3415×10^{-6}
C_{15}	-2.8610×10^{-6}	C_{17}	1.3623×10^{-7}	C_{19}	2.9234×10^{-8}
C_{21}	-5.0012×10^{-9}				

FFS②

C_4	-4.2973×10^{-2}	C_6	3.8451×10^{-2}	C_8	3.6896×10^{-3}
C_{10}	5.7252×10^{-3}	C_{11}	1.4826×10^{-4}	C_{13}	-1.1264×10^{-3}
C_{15}	4.7888×10^{-4}				

FFS③

C_4	2.0862×10^{-2}	C_6	1.8162×10^{-2}	C_8	1.4311×10^{-4}
C_{10}	-2.1971×10^{-5}	C_{11}	1.3347×10^{-5}	C_{13}	2.3775×10^{-5}
C_{15}	7.6542×10^{-6}				

Displacement and tilt(1)

X	0.00	Y	12.30	Z	38.14
α	-1.09	β	0.00	γ	0.00

Displacement and tilt(2)

X	0.00	Y	-0.33	Z	45.00
α	-31.99	β	0.00	γ	0.00

Displacement and tilt(3)

X	0.00	Y	19.10	Z	42.18
α	78.03	β	0.00	γ	0.00

Displacement and tilt(4)

X	0.00	Y	39.78	Z	60.30
α	-147.16	β	0.00	γ	0.00

Displacement and tilt(5)

X	0.00	Y	32.00	Z	40.06
α	0.00	β	0.00	γ	0.00

Displacement and tilt(6)

X	0.00	Y	32.00	Z	37.55
α	0.00	β	0.00	γ	0.00

Displacement and tilt(7)

X	0.00	Y	32.00	Z	31.96
α	0.00	β	0.00	γ	0.00

Example 2 4

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	ASS①		(1)	1.5254	56.2
3	FFS① (RE)		(2)	1.5254	56.2
4	ASS① (RE)		(1)	1.5254	56.2
5	FFS②		(3)		

6	FFS③ (RE)	(4)		
7	10.00	(5)	1.7400	45.0
8	-30.00	(6)	1.4875	70.2
9	20.00	(7)		
Image plane	∞	(8)		

ASS①

R -755.72

K 0.0000

A -3.0223×10^{-6}

B 3.6982×10^{-9}

FFS①

C_4	-1.3291×10^{-2}	C_6	-9.1362×10^{-3}	C_8	1.3010×10^{-5}
C_{10}	-4.7998×10^{-5}	C_{11}	3.8631×10^{-6}	C_{13}	1.2388×10^{-6}
C_{15}	-1.7387×10^{-6}	C_{17}	4.1889×10^{-7}	C_{19}	3.3450×10^{-8}
C_{21}	1.5434×10^{-8}				

FFS②

C_4	-4.9441×10^{-2}	C_6	5.0481×10^{-2}	C_8	-1.8555×10^{-3}
C_{10}	1.1867×10^{-3}	C_{11}	-1.0276×10^{-3}	C_{13}	2.6209×10^{-3}
C_{15}	1.5800×10^{-4}				

FFS③

C_4	2.1838×10^{-2}	C_6	2.0822×10^{-2}	C_8	1.5599×10^{-4}
C_{10}	2.2274×10^{-5}	C_{11}	1.7287×10^{-5}	C_{13}	3.1039×10^{-5}
C_{15}	1.7347×10^{-5}				

Displacement and tilt(1)

X	0.00	Y	15.24	Z	38.77
α	2.68	β	0.00	γ	0.00

Displacement and tilt(2)

X	0.00	Y	0.01	Z	47.98
α	-29.39	β	0.00	γ	0.00

Displacement and tilt(3)

X	0.00	Y	22.36	Z	42.21
α	83.11	β	0.00	γ	0.00

Displacement and tilt(4)

X	0.00	Y	38.88	Z	54.46
α	-145.16	β	0.00	γ	0.00

Displacement and tilt(5)

X	0.00	Y	32.00	Z	34.24
α	0.00	β	0.00	γ	0.00

Displacement and tilt(6)

X	0.00	Y	32.00	Z	33.17
α	0.00	β	0.00	γ	0.00

Displacement and tilt(7)

X	0.00	Y	32.00	Z	30.48
α	0.00	β	0.00	γ	0.00

Displacement and tilt(8)

X	0.00	Y	32.00	Z	28.00
α	0.00	β	0.00	γ	0.00

Example 2 5

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	ASS①		(1)	1.5254	56.2

3	FFS① (RE)	(2)	1.5254	56.2
4	ASS① (RE)	(1)	1.5254	56.2
5	FFS②	(3)		
6	FFS③ (RE)	(4)		
7	FFS④ (RE)	(5)		
Image plane	∞	(6)		

ASS①

R -142.30

K 0.0000

A -7.9459×10^{-6}

B 4.5193×10^{-9}

FFS①

C_4	-1.5782×10^{-2}	C_6	-9.2595×10^{-3}	C_8	8.4720×10^{-5}
C_{10}	4.5249×10^{-5}	C_{11}	1.0602×10^{-5}	C_{13}	-8.7497×10^{-6}
C_{15}	-4.4525×10^{-6}	C_{17}	-5.8969×10^{-8}	C_{19}	1.8760×10^{-7}
C_{21}	1.2837×10^{-7}				

FFS②

C_4	-4.8446×10^{-2}	C_6	-8.3829×10^{-3}

FFS③

C_4	1.6543×10^{-2}	C_6	9.5400×10^{-3}	C_8	-1.0953×10^{-4}
C_{10}	-1.8587×10^{-5}	C_{11}	5.3062×10^{-6}	C_{13}	7.9992×10^{-6}
C_{15}	5.7816×10^{-6}				

FFS④

C_4	-4.2215×10^{-3}	C_6	1.0692×10^{-2}	C_8	-3.6896×10^{-4}
C_{10}	-2.5259×10^{-4}	C_{11}	5.9277×10^{-6}	C_{13}	-1.3516×10^{-5}
C_{15}	-7.8520×10^{-6}				

Displacement and tilt(1)

X	0.00	Y	11.67	Z	32.96
α	-1.41	β	0.00	γ	0.00

Displacement and tilt(2)

X	0.00	Y	-0.45	Z	40.56
α	-30.45	β	0.00	γ	0.00

Displacement and tilt(3)

X	0.00	Y	18.56	Z	37.77
α	33.95	β	0.00	γ	0.00

Displacement and tilt(4)

X	0.00	Y	43.39	Z	48.16
α	-135.03	β	0.00	γ	0.00

Displacement and tilt(5)

X	0.00	Y	36.28	Z	31.09
α	6.39	β	0.00	γ	0.00

Displacement and tilt(6)

X	0.00	Y	32.00	Z	55.72
α	0.00	β	0.00	γ	0.00

Example 26

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	FFS①		(1)	1.5254	56.2
3	FFS② (RE)		(2)	1.5254	56.2
4	FFS③		(3)		
5	FFS④		(4)	1.5254	56.2

6	FFS⑤ (RE)	(5)	1.5254	56.2
7	FFS⑥	(6)		
Image plane	∞	(7)		

FFS①

C_4 -6.2629×10^{-3} C_6 3.3796×10^{-4} C_8 3.9666×10^{-4}

C_{10} -1.2581×10^{-4} C_{11} 2.6158×10^{-6} C_{13} 3.2906×10^{-5}

C_{15} 1.4501×10^{-6}

FFS②

C_4 -1.3276×10^{-2} C_6 -9.4693×10^{-3} C_8 -8.4725×10^{-5}

C_{10} -1.3499×10^{-4} C_{11} -2.9102×10^{-6} C_{13} -2.0112×10^{-6}

C_{15} -2.4589×10^{-6} C_{17} -4.4244×10^{-9} C_{19} -4.8328×10^{-8}

C_{21} -1.8143×10^{-8}

FFS③

C_4 -2.1469×10^{-2} C_6 -3.3694×10^{-2} C_8 -1.6179×10^{-3}

C_{10} -3.2678×10^{-3} C_{11} -7.9899×10^{-5} C_{13} -1.7505×10^{-4}

C_{15} -3.5647×10^{-4}

FFS④

C_4 -1.1648×10^{-1} C_6 -4.0332×10^{-2} C_8 -1.1348×10^{-3}

C_{10} 1.9930×10^{-3} C_{11} 8.3579×10^{-4} C_{13} 8.0595×10^{-4}

C_{15} 9.9925×10^{-4}

FFS⑤

C_4 1.9541×10^{-2} C_6 1.6255×10^{-2} C_8 -1.0516×10^{-5}

C_{10} -5.5991×10^{-5} C_{11} 4.5526×10^{-6} C_{13} 1.2743×10^{-5}

C_{15} 3.8394×10^{-6}

FFS⑥

C_4 1.9172×10^{-2} C_6 3.2175×10^{-2} C_{11} 9.6401×10^{-5}

C_{13} -2.6951×10^{-5} C_{15} -1.6440×10^{-4}

Displacement and tilt(1)

X	0.00	Y	0.00	Z	32.45
α	-13.66	β	0.00	γ	0.00

Displacement and tilt(2)

X	0.00	Y	-1.36	Z	48.79
α	-33.83	β	0.00	γ	0.00

Displacement and tilt(3)

X	0.00	Y	12.70	Z	41.59
α	-50.46	β	0.00	γ	0.00

Displacement and tilt(4)

X	0.00	Y	19.62	Z	39.02
α	-65.04	β	0.00	γ	0.00

Displacement and tilt(5)

X	0.00	Y	42.00	Z	30.00
α	-44.81	β	0.00	γ	0.00

Displacement and tilt(6)

X	0.00	Y	32.00	Z	45.53
α	0.00	β	0.00	γ	0.00

Displacement and tilt(7)

X	0.00	Y	32.00	Z	53.23
α	0.00	β	0.00	γ	0.00

Example 27

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				

2	ＡＳＳ①	(1)	1.5254	56.2
3	ＦＦＳ①（ＲＥ）	(2)	1.5254	56.2
4	ＡＳＳ①（ＲＥ）	(1)	1.5254	56.2
5	ＦＦＳ①（ＲＥ）	(2)	1.5254	56.2
6	ＦＦＳ②	(3)		
7	ＦＦＳ③	(4)	1.5254	56.2
8	ＦＦＳ④（ＲＥ）	(5)	1.5254	56.2
9	ＦＦＳ⑤	(6)		
Image plane	∞	(7)		

ＡＳＳ①

R -109.37

K 0.0000

A 2.7422×10^{-5}

B -4.1869×10^{-8}

ＦＦＳ①

C_4 -1.1126×10^{-2} C_6 -1.0227×10^{-2} C_8 -6.0588×10^{-5}

C_{10} -3.0318×10^{-5} C_{11} 7.9055×10^{-6} C_{13} 1.1105×10^{-5}

C_{15} 1.0604×10^{-6} C_{17} 2.8597×10^{-7} C_{19} 1.5498×10^{-7}

C_{21} 1.4283×10^{-7}

ＦＦＳ②

C_4 3.6878×10^{-2} C_6 3.5702×10^{-2} C_8 -2.0106×10^{-2}

C_{10} -9.8201×10^{-3} C_{11} 2.1010×10^{-3} C_{13} -1.9983×10^{-3}

C_{15} 9.8827×10^{-4}

ＦＦＳ③

C_4 -1.0254×10^{-1} C_6 -2.5575×10^{-2} C_8 -2.0239×10^{-2}

C_{10} -5.8721×10^{-3} C_{11} 1.0962×10^{-3} C_{13} -3.3381×10^{-3}

C_{15} 4.7815×10^{-4}

FFS④

C_4	2.3287×10^{-2}	C_6	1.8127×10^{-2}	C_8	-4.0703×10^{-4}
C_{10}	-2.4676×10^{-4}	C_{11}	1.9470×10^{-5}	C_{13}	3.1178×10^{-5}
C_{15}	-3.0929×10^{-7}				

FFS⑤

C_4	-1.9980×10^{-2}	C_6	-1.9644×10^{-2}	C_{11}	1.8913×10^{-4}
C_{13}	4.0095×10^{-4}	C_{15}	5.1524×10^{-4}		

Displacement and tilt(1)

X	0.00	Y	6.56	Z	32.12
α	-2.57	β	0.00	γ	0.00

Displacement and tilt(2)

X	0.00	Y	-0.19	Z	38.74
α	-23.54	β	0.00	γ	0.00

Displacement and tilt(3)

X	0.00	Y	20.79	Z	39.32
α	-71.99	β	0.00	γ	0.00

Displacement and tilt(4)

X	0.00	Y	21.54	Z	38.60
α	-84.73	β	0.00	γ	0.00

Displacement and tilt(5)

X	0.00	Y	36.81	Z	30.00
α	-35.69	β	0.00	γ	0.00

Displacement and tilt(6)

X	0.00	Y	32.00	Z	44.11
α	0.00	β	0.00	γ	0.00

Displacement and tilt(7)

X	0.00	Y	32.00	Z	50.34
α	0.00	β	0.00	γ	0.00

Example 28

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	FFS①		(1)	1.5254	56.2
3	FFS② (RE)		(2)	1.5254	56.2
4	FFS③ (RE)		(3)	1.5254	56.2
5	FFS④		(4)		
6	FFS⑤		(5)	1.5254	56.2
7	FFS⑥ (RE)		(6)	1.5254	56.2
8	FFS⑦ (RE)		(7)	1.5254	56.2
9	FFS⑧		(8)		
Image plane	∞		(9)		

FFS①

C_4 -8.4040×10^{-3} C_6 -8.5943×10^{-3}

FFS②

C_4 -4.8109×10^{-3} C_6 -3.4151×10^{-3} C_8 7.6983×10^{-6}

C_{10} 5.9643×10^{-6}

FFS③

C_4 8.5504×10^{-4} C_6 2.0899×10^{-3} C_8 3.9710×10^{-6}

C_{10} 1.2427×10^{-5}

FFS④

C_4 -4.1338×10^{-3} C_6 4.6863×10^{-3}

FFS⑤

C_4 1.8948×10^{-2} C_6 7.8112×10^{-3}

FFS⑥

C_4 -2.9136×10^{-3} C_6 -2.6792×10^{-3}

FFS⑦

C_4 1.0066×10^{-2} C_6 1.0913×10^{-2}

FFS⑧

C_4 -2.2044×10^{-2} C_6 -1.6909×10^{-2}

Displacement and tilt(1)

X 0.00 Y 0.00 Z 30.00

α 0.00 β 0.00 γ 0.00

Displacement and tilt(2)

X 0.00 Y 7.73 Z 66.05

α 18.69 β 0.00 γ 0.00

Displacement and tilt(3)

X 0.00 Y -17.85 Z 38.62

α 46.96 β 0.00 γ 0.00

Displacement and tilt(4)

X 0.00 Y 20.71 Z 58.27

α 70.85 β 0.00 γ 0.00

Displacement and tilt(5)

X 0.00 Y 21.56 Z 58.79

α 72.18 β 0.00 γ 0.00

Displacement and tilt(6)

X 0.00 Y 41.10 Z 68.55

α 46.38 β 0.00 γ 0.00

Displacement and tilt(7)

X 0.00 Y 28.64 Z 46.33

α 17.45 β 0.00 γ 0.00

Displacement and tilt(8)

X	0.00	Y	32.02	Z	71.98
α	0.00	β	0.00	γ	0.00

Displacement and tilt(9)

X	0.00	Y	32.00	Z	76.97
α	0.00	β	0.00	γ	0.00

Example 2 9

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	ASS①		(1)	1.5254	56.2
3	FFS① (RE)		(2)	1.5254	56.2
4	ASS① (RE)		(1)	1.5254	56.2
5	FFS②		(3)		
6	FFS③		(4)	1.5254	56.2
7	FFS④ (RE)		(5)	1.5254	56.2
8	FFS⑤		(6)		
Image plane	∞		(7)		

ASS①

R 1285.39

K 0.0000

A 6.4599×10^{-7}

B -3.7861×10^{-10}

FFS①

C_4	-3.6795×10^{-3}	C_6	-2.1319×10^{-3}	C_8	-5.8405×10^{-5}
C_{10}	-6.5664×10^{-5}	C_{11}	8.2431×10^{-7}	C_{13}	1.4603×10^{-6}
C_{15}	1.4571×10^{-6}	C_{17}	-5.6374×10^{-8}	C_{19}	-3.7292×10^{-8}
C_{21}	-4.3730×10^{-8}				

FFS②

C_4	-3.1489×10^{-4}	C_6	5.2538×10^{-3}	C_8	1.2817×10^{-3}
C_{10}	1.2156×10^{-3}	C_{11}	5.1327×10^{-6}	C_{13}	-1.0362×10^{-5}
C_{15}	4.7618×10^{-5}				

FFS③

C_4	-2.2969×10^{-3}	C_6	-4.7767×10^{-4}	C_8	3.1569×10^{-4}
C_{10}	1.9939×10^{-4}	C_{11}	4.1969×10^{-7}	C_{13}	1.3660×10^{-5}
C_{15}	4.6817×10^{-6}				

FFS④

C_4	2.2969×10^{-3}	C_6	4.7767×10^{-4}	C_8	-3.1569×10^{-4}
C_{10}	-1.9939×10^{-4}	C_{11}	-4.1969×10^{-7}	C_{13}	-1.3660×10^{-5}
C_{15}	-4.6817×10^{-6}				

FFS⑤

C_4	2.5793×10^{-2}	C_6	-4.2457×10^{-3}	C_{11}	-4.8745×10^{-4}
C_{13}	-1.7443×10^{-4}	C_{15}	-3.6717×10^{-5}		

Displacement and tilt(1)

X	0.00	Y	10.19	Z	29.40
α	7.35	β	0.00	γ	0.00

Displacement and tilt(2)

X	0.00	Y	-3.29	Z	36.33
α	-25.35	β	0.00	γ	0.00

Displacement and tilt(3)

X	0.00	Y	24.99	Z	36.53
α	82.49	β	0.00	γ	0.00

Displacement and tilt(4)

X	0.00	Y	18.12	Z	7.32
α	-18.71	β	0.00	γ	0.00

Displacement and tilt(5)

X	0.00	Y	18.12	Z	-7.32
α	18.71	β	0.00	γ	0.00

Displacement and tilt(6)

X	0.00	Y	24.00	Z	0.00
α	90.00	β	0.00	γ	0.00

Displacement and tilt(7)

X	0.00	Y	0.00	Z	1.73
α	0.00	β	0.00	γ	0.00

Example 30

Surface No.	Radius of curvature	Surface separation	Displacement and tilt	Refractive index	Abbe's No.
Object plane	∞	-1000.00			
1	∞ (Stop)				
2	ASS①		(1)	1.5254	56.2
3	FFS① (RE)		(2)	1.5254	56.2
4	ASS① (RE)		(1)	1.5254	56.2
5	FFS②		(3)		
6	FFS③		(4)	1.5254	56.2
7	FFS④ (RE)		(5)	1.5254	56.2
8	FFS⑤		(6)		
Image plane	∞		(7)		

ASS①

R 368.58

K 0.0000

A 7.6841×10^{-7}

B -3.6756×10^{-11}

FFS①

C_4 -2.7696×10^{-3} C_6 -1.4546×10^{-3} C_8 -5.7608×10^{-5}

C_{10} -9.2334×10^{-5} C_{11} 5.8163×10^{-7} C_{13} 3.5074×10^{-6}

C_{15} 2.2152×10^{-6} C_{17} -1.8054×10^{-7} C_{19} -1.1334×10^{-7}

C_{21} -1.0782×10^{-7}

FFS②

C_4 3.3609×10^{-4} C_6 8.4179×10^{-2} C_8 -3.1419×10^{-5}

C_{10} 3.1128×10^{-3} C_{11} 3.4030×10^{-5} C_{13} -1.1634×10^{-4}

C_{15} 3.9570×10^{-5}

FFS③

C_4 -3.7622×10^{-3} C_6 -3.6532×10^{-3} C_8 1.5526×10^{-4}

C_{10} -5.4887×10^{-6} C_{11} -7.4035×10^{-6} C_{13} 1.0763×10^{-5}

C_{15} -6.6288×10^{-7}

FFS④

C_4 3.7622×10^{-3} C_6 3.6532×10^{-3} C_8 -1.5526×10^{-4}

C_{10} 5.4887×10^{-6} C_{11} 7.4035×10^{-6} C_{13} -1.0763×10^{-5}

C_{15} 6.6288×10^{-7}

FFS⑤

C_4 2.8169×10^{-2} C_6 4.5388×10^{-4} C_{11} -4.5848×10^{-4}

C_{13} -8.7689×10^{-5} C_{15} -8.8053×10^{-6}

Displacement and tilt(1)

X 0.00 Y 17.47 Z 30.07

α -1.32 β 0.00 γ 0.00

Displacement and tilt(2)

X	0.00	Y	0.39	Z	38.40
α	-28.76	β	0.00	γ	0.00

Displacement and tilt(3)

X	0.00	Y	30.09	Z	31.35
α	36.81	β	0.00	γ	0.00

Displacement and tilt(4)

X	0.00	Y	19.88	Z	6.67
α	-15.86	β	0.00	γ	0.00

Displacement and tilt(5)

X	0.00	Y	19.88	Z	-6.67
α	15.86	β	0.00	γ	0.00

Displacement and tilt(6)

X	0.00	Y	29.00	Z	0.00
α	90.00	β	0.00	γ	0.00

Displacement and tilt(7)

X	0.00	Y	0.00	Z	1.82
α	0.00	β	0.00	γ	0.00

上記実施例１６、２０、２２、２９、３０の横収差をそれぞれ図３４、図３５、図３６、図３７、図３８に示す。これらの横収差図において、括弧内に示された数字は（水平画角，垂直画角）を表し、その画角における横収差を示す。

なお、上記実施例１６～２８の後記条件式（４）、（６）の値は次の通りである。

	条件式（４）θ_1 （°）	条件式（６）ΣD_1 （mm）
実施例16	22.5	119.4
実施例17	41.0	57.7
実施例18	37.2	62.5

実施例19	22.0	33.4
実施例20	26.1	99.4
実施例21	18.8	92.7
実施例22	25.6	95.7
実施例23	41.2	58.3
実施例24	36.6	50.1
実施例25	22.7	70.4
実施例26	20.4	78.5
実施例27	43.8	56.2
実施例28	31.2	117.5

次に、上記実施例２９、３０の前記条件式（１）～（３）に関する値を下記に示す。

		実施例２９	実施例３０
条件式（１）	α	43°$\leqq\alpha\leqq$54°	43°$\leqq\alpha\leqq$58°
条件式（２）	β	19°	18°
条件式（３）	D	27.5mm	31mm
	L	72mm	72mm
	D／L	0.38	0.43

なお、上記実施例１６～３０の各自由曲面は、平面を含む球面、非球面、アナモフィック面、アナモフィック非球面に置き換えることも可能である。

ところで、以上のような本発明の画像表示装置の光学系において、画像表示素子３の表示する像中心と右眼用接眼プリズム２Ｒの形成する右側瞳４Ｒ中心とを通る光線を右側光軸とし、画像表示素子３の表示する像中心と左眼用接眼プリズム２Ｌの形成する左側瞳４Ｌ中心とを通る光線を左側光軸としたときに、光路振分けミラー１又は光路振分けプリズム１０から右眼用接眼プリズム２Ｒ及び左眼用接眼プリズム２Ｌに入射する右側光軸及び左側光軸と画像表示素子３の表示面

とのなす角度の絶対値をθ_1とするとき、

$$10° < \theta_1 < 60° \quad \cdots (4)$$

を満足するように構成されていることが望ましい。

上記条件式（４）は、光路振分けミラー１又は光路振分けプリズム１０からなる光路振り分け手段から接眼プリズム２Ｒ、２Ｌに入射するときの軸上主光線と画像表示素子３とのなす角度を制限するものである。

上記条件式（４）の下限の１０°を越えると、光路振り分け手段から接眼プリズムに入射する軸上主光線が画像表示素子と略平行な光路をなってしまい、左右の光路を確保することが難しくなり、１つのＬＣＤ等の画像表示素子から左右の接眼プリズムに光路を振り分けるためにはハーフミラーを使用しなければならなくなり、画像が暗くなるため好ましくない。上記条件式（４）の上限の６０°を越えると、接眼プリズムを大きく傾けるか、あるいは、プリズム自体を大きくする必要があり、光学系の小型化・軽量化が達成できなくなる。

上記条件式はさらに以下の条件式（５）であることが望ましい。

$$15° < \theta_1 < 50° \quad \cdots (5)$$

上記条件式の範囲内であれば、左右の光路を確保しながら装置の更なる小型化が達成できる。

また、画像表示素子３から右眼用接眼プリズム２Ｒ及び左眼用接眼プリズム２Ｌの入射面２１Ｒ、２１Ｌまでの光軸上の距離をΣD_1とすると、

$$20\,\mathrm{mm} < \Sigma D_1 < 150\,\mathrm{mm} \quad \cdots (6)$$

を満足するように構成されていることが望ましい。

上記条件式（６）は、装置の小型化を達成するための条件式であり、画像表示素子３から接眼プリズム２Ｒ、２Ｌまでの軸上主光線の光路長を規定したものである。

上記条件式（６）の下限の２０ｍｍを越えると、光路振り分け手段の各面のパワーが非常に強くなり、偏心収差、特に偏心コマ収差が良好に補正できなくなる。また、画像表示素子３と光線との角度（主光線傾角）が非常に大きくなり、好ましくない。また、上記条件式（６）の上限の１５０ｍｍを越えるを、光路振り

分け手段が大きくなり、接眼プリズムと比較して大きく突出した形状になってしまうため好ましくない。

上記条件式はさらに以下の条件式（７）であることが望ましい。

$$30\,\mathrm{mm} < \Sigma D_1 < 130\,\mathrm{mm} \quad \cdots (7)$$

上記条件式の範囲内であれば、性能を良好に保ちながら装置の更なる小型化が達成できる。

上記条件式はさらに以下の条件式（８）であることが望ましい。

$$45\,\mathrm{mm} < \Sigma D_1 < 120\,\mathrm{mm} \quad \cdots (8)$$

上記条件式の範囲内であれば、性能を良好に保ちながら装置の更なる小型化が達成できる。

さて、本発明の画像表示装置の以上のよう光学系において、図３９に例示するように、左右眼用の偏心プリズム体２Ｌ、２Ｒの外界側（観察者顔面側と反対側）の反射面２３Ｌ、２３Ｒ（図２６の場合は、反射面２２Ｌ、２２Ｒ。図２７の場合は、２２Ｌ、２２Ｒ、２４Ｒ、２４Ｒ。図２８の場合は、２３Ｌ、２３Ｒ。）をハーフミラー面として、その外界側に光路の曲がりを補償する補償プリズム１６Ｌ、１６Ｒを貼り付けるか若干離間して配置し、その補償プリズム１６Ｌ、１６Ｒの外界側の面１７Ｌ、１７Ｒを左右眼用の偏心プリズム体２Ｌ、２Ｒの観察者顔面側の透過面２４Ｌ、２４Ｒ（図２６の場合は、透過面２３Ｌ、２３Ｒ。図２７の場合は、２５Ｌ、２５Ｒ。図２８の場合は、２４Ｌ、２４Ｒ。）と略同じ形状の面とすることにより、外界からの光が略直通して外界のシースルー観察が可能になる。この場合は、補償プリズム１６Ｌ、１６Ｒの外界側に液晶シャッター等の外界光の透過率を切り換える手段を配置すれば、スーパーインポーズ機能やシースルー機能が付加できる。

また、本発明において、画像表示素子３として、前記したように、透過型あるいは反射型のＬＣＤ（液晶表示素子）を用いることができるが、自己発光型パネルを使うことにより構造を簡単にして、軽量の画像表示装置を構成することができる。画像表示素子３にＬＣＤを用いると、バックライト等の照明光源が必要となる問題点と、ＬＣＤの場合は偏光板を必ず必要として、照明光の半分しか表示

に使うことができない問題点がある。

そこで、自己発光型パネル（ディスプレイ）を用いることが望ましい。自己発光型パネルには、ＯＬＥＤ（Ｏｒｇａｎｉｃ　Ｌｉｇｈｔ　Ｅｍｉｔｔｉｎｇ　Ｄｉｏｄｅｓ）やＬＥＤ（Ｌｉｇｈｔ　Ｅｍｉｔｔｉｎｇ　Ｄｉｏｄｅｓ）、図４０にその構造を例示したようなＥＬ（Ｅｌｅｃｔｒｏｌｕｍｉｎｅｓｃｅｎｃｅ）パネル等がある。

図４０は、３層構成の有機ＥＬの構造を示すもので、Ｓｉ基板上に設けられ各画素毎にスイッチング素子が配置された画素電極と、ガラス基板の下面に設けられた共通電極のＩＴＯ膜との間に、正孔注入層と有機ＥＬ層と電子注入層との３層からなる有機ＥＬ層が挟持され、スイッチング素子の作用で画素電極とＩＴＯ膜との間に電圧が印加されると、正孔注入層からは正孔が、電子注入層からは電子が有機ＥＬ層中に注入され、有機ＥＬ層中で再結合することにより、その画素の有機ＥＬ層が発光することになり、所要の画像が表示される。

このような発光型ディスプレイを画像表示装置に使うメリットは、その視野角特性の良さにある。特に、両眼視する頭部装着式画像表示装置（ＨＭＤ）においては、観察者の眼幅の違いやＨＭＤ本体のずれ等により、光学系の瞳と観察者の瞳がずれることがある。観察者の瞳がずれても観察像が陰らないようにするには、光学系の瞳を広い範囲で収差がないようにするのが重要である。光学系の設計において、瞳を広く設計しても、瞳がずれた場合は、接眼光学系を通して見ると、画像表示素子を斜めから観察している状態となる。一般に、ＬＣＤの画像表示素子はこの斜めから見る視野角特性が良くなく、コントラストが低下したり白黒が反転した観察像しか観察することができなくなってしまう。そのため、ＨＭＤの装着位置により画面の明るさやコントラストが変化してしまい、安定した画質で観察することが難しい。発光型画像表示素子では、このような問題が発生し難く、このため、ＨＭＤ用画像表示素子として好ましいものである。

さて、以上に説明したような本発明の画像表示装置を１組用意して支持することにより、据え付け型又はポータブル型の画像表示装置として構成することができる。その様子を図４１に示す。図４１中、３１は表示装置本体部を示し、観察

者の顔面の両眼の前方に保持されるよう支持部材が頭部を介して固定している。その支持部材としては、一端を表示装置本体部３１に接合し、観察者のこめかみから耳の上部にかけて延在する左右の前フレーム３２と、前フレーム３２の他端に接合され、観察者の側頭部を渡るように延在する左右の後フレーム３３とから、あるいは、さらに、左右の後フレーム３３の他端に挟まれるように自らの両端を一方づつ接合し、観察者の頭頂部を支持する頭頂フレーム３４とから構成されている。

また、前フレーム３２における上記の後フレーム３３との接合近傍には、弾性体からなり例えば金属板バネ等で構成されたリヤプレート３５が接合されている。このリヤプレート３５は、上記支持部材の一翼を担うリヤカバー３６が観察者の後頭部から首のつけねにかかる部分で耳の後方に位置して支持可能となるように接合されている。リヤプレート３５又はリヤカバー３６内にの観察者の耳に対応する位置にスピーカー３９が取り付けられている。

映像・音声信号等を外部から送信するためのケーブル４１が表示装置本体部３１から、頭頂フレーム３４、後フレーム３３、前フレーム３２、リヤプレート３５の内部を介してリヤプレート３５あるいはリヤカバー３６の後端部より外部に突出している。そして、このケーブル４１はビデオ再生装置４０に接続されている。なお、図中、４０ａはビデオ再生装置４０のスイッチやボリュウム調整部である。

なお、ケーブル４１は先端をジャックして、既存のビデオデッキ等に取り付け可能としてもよい。さらに、ＴＶ電波受信用チューナーに接続してＴＶ鑑賞用としてもよいし、コンピュータに接続してコンピュータグラフィックスの映像や、コンピュータからのメッセージ映像等を受信するようにしてもよい。また、邪魔なコードを排斥するために、アンテナを接続して外部からの信号を電波によって受信するようにしても構わない。

産業上の利用可能性

以上の説明から明らかなように、本発明によると、１つの画像表示素子からの

画像を、ハーフミラーを利用せずに両眼に導き明るく観察でき、さらに、両眼の中央に配置する光路振分けミラーあるいは光路振分けプリズムを持たせることで、諸収差の補正を容易にして、頭部装着式画像表示装置等の画像表示装置を提供することができる。また、このような構成において、表示画像を左右で切り換えずに使用できる単板両眼視に最適な照明配置を得ることができる。

請 求 の 範 囲

〔1〕 観察者が観察する画像を表示する画像表示素子と、前記画像を右眼用光路と左眼用光路とに振分ける光路振分けミラーと、前記光路振分けミラーの右側に配置された右眼用接眼プリズムと、前記光路振分けミラーの左側に配置された左眼用接眼プリズムとを有し、

前記光路振分けミラーが、前記画像表示素子に対向配置され前記画像表示素子から射出された表示光束を、前記右眼用接眼プリズムと前記左眼用プリズムとに振分けて反射するミラー面を有し、前記ミラー面が、偏心収差を補正する回転非対称な曲面形状にて構成され、

前記右眼用接眼プリズムが、前記光路振分けミラーで反射された右眼用光路の光束をプリズム内に入射させる第1面と、プリズム内で右眼用光路の光束を反射する第2面と、プリズム外に右眼用光路の光束を射出する第3面とを有し、

前記左眼用接眼プリズムが、前記光路振分けミラーで反射された左眼用光路の光束をプリズム内に入射させる第1面と、プリズム内で左眼用光路の光束を反射する第2面と、プリズム外に左眼用光路の光束を射出する第3面とを有し、

少なくとも、前記右眼用接眼プリズムの反射作用面である第2面と、前記左眼用接眼プリズムの反射作用面である第2面とが、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする画像表示装置。

〔2〕 前記光路振分けミラーの有する回転非対称な曲面形状が、唯一の対称面を備えた自由曲面にて構成されていることを特徴とする請求項1記載の画像表示装置。

〔3〕 前記光路振分けミラーの有する自由曲面が、前記画像表示素子の表示する像中心と前記右眼用接眼プリズムの形成する右側瞳中心と前記左眼用接眼プリズムの形成する左側瞳中心とを結んだ面（Y－Z平面）を前記唯一の対称面として構成されていることを特徴とする請求項2記載の画像表示装置。

〔4〕 前記画像表示素子が、前後方向（Z方向）で前記光路振分けミラー

と観察者との間に配置され、かつ、左右方向（Y方向）で前記右眼用接眼プリズムと前記左眼用接眼プリズムとの間に配置されて構成されていることを特徴とする請求項1～3の何れか1項記載の画像表示装置。

〔5〕　前記画像表示素子と前記光路振分けミラーの間に、光束に負のパワーを与える負レンズを配置して構成されていることを特徴とする請求項1～3の何れか1項記載の画像表示装置。

〔6〕　前記右眼用接眼プリズムが、前記光路振分けミラーから射出され前記第1面を透過してプリズム内に入射した光束を全反射臨界角よりも大きい角度で前記第3面に入射させることによって全反射作用によりプリズム内で前記第2面に向けて反射させ、前記第2面で反射した光束を全反射臨界角よりも小さい角度で前記第3面に入射させることによってこの第3面を透過させて光束をプリズム外に射出させるように構成され、

前記左眼用接眼プリズムが、前記光路振分けミラーから射出され前記第1面を透過してプリズム内に入射した光束を全反射臨界角よりも大きい角度で前記第3面に入射させることによって全反射作用によりプリズム内で前記第2面に向けて反射させ、前記第2面で反射した光束を全反射臨界角よりも小さい角度で前記第3面に入射させることによってこの第3面を透過させて光束をプリズム外に射出させるように構成されていることを特徴とする請求項1～3の何れか1項記載の画像表示装置。

〔7〕　前記右眼用接眼プリズムの前記第1面が、偏心収差を補正する回転非対称な曲面形状にて構成され、

前記左眼用接眼プリズムの前記第1面が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項1～3の何れか1項記載の画像表示装置。

〔8〕　前記右眼用接眼プリズムの前記第1面が有する回転非対称な曲面形状が、唯一の対称面を備えた自由曲面にて構成され、

前記左眼用接眼プリズムの前記第1面が有する回転非対称な曲面形状が、唯一の対称面を備えた自由曲面にて構成されていることを特徴とする請求項7記載の

画像表示装置。

〔９〕　前記右眼用接眼プリズムの前記第１面が有する自由曲面が、前記画像表示素子の表示する像中心と前記右眼用接眼プリズムの形成する右側瞳中心とを通る光線を光軸としたときに、プリズム内での折り返し光路中の光軸を含んだ面（Ｙ－Ｚ面）を前記唯一の対称面として構成され、

前記左眼用接眼プリズムの前記第１面が有する自由曲面が、前記画像表示素子の表示する像中心と前記左眼用接眼プリズムの形成する右側瞳中心とを通る光線を光軸としたときに、プリズム内での折り返し光路中の光軸を含んだ面（Ｙ－Ｚ面）を前記唯一の対称面として構成されていることを特徴とする請求項８記載の画像表示装置。

〔１０〕　前記右眼用接眼プリズムの前記第３面が、偏心収差を補正する回転非対称な曲面形状にて構成され、

前記左眼用接眼プリズムの前記第３面が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項１～３の何れか１項記載の画像表示装置。

〔１１〕　前記右眼用接眼プリズムの前記第３面が有する回転非対称な曲面形状が、唯一の対称面を備えた自由曲面にて構成され、

前記左眼用接眼プリズムの前記第３面が有する回転非対称な曲面形状が、唯一の対称面を備えた自由曲面にて構成されていることを特徴とする請求項１０記載の画像表示装置。

〔１２〕　前記右眼用接眼プリズムの前記第３面が有する自由曲面が、前記画像表示素子の表示する像中心と前記右眼用接眼プリズムの形成する右側瞳中心とを通る光線を光軸としたときに、プリズム内での折り返し光路中の光軸を含んだ面（Ｙ－Ｚ面）を前記唯一の対称面として構成され、

前記左眼用接眼プリズムの前記第３面が有する自由曲面が、前記画像表示素子の表示する像中心と前記左眼用接眼プリズムの形成する右側瞳中心とを通る光線を光軸としたときに、プリズム内での折り返し光路中の光軸を含んだ面（Ｙ－Ｚ面）を前記唯一の対称面として構成されていることを特徴とする請求項１１記載

の画像表示装置。

〔１３〕　前記右眼用接眼プリズムの前記第３面が、回転対称非球面にて構成され、

前記左眼用接眼プリズムの前記第３面が、回転対称非球面にて構成されていることを特徴とする請求項１～３の何れか１項記載の画像表示装置。

〔１４〕　観察者が観察する画像を表示する画像表示素子と、前記画像を右眼用光路と左眼用光路とに振分ける光路振分けプリズムと、前記光路振分けプリズムの右側に配置された右眼用接眼プリズムと、前記光路振分けプリズムの左側に配置された左眼用接眼プリズムとを有し、

前記光路振分けプリズムが、前記画像表示素子に対向配置され前記画像表示素子から射出された表示光束をプリズム内部に入射させる第１面と、前記第１面から入射した前記右眼用光路を反射する第２１面と、前記第１面から入射した前記左眼用光路を反射する第２２面と、前記右眼用光路の光束をプリズム外に射出させる第３１面と、前記左眼用光路の光束をプリズム外に射出させる第３２面と、を少なくとも有し、

前記光路振分けプリズムは、前記右眼用光路中に前記画像表示素子の表示した像から右眼用リレー像を形成し、かつ、前記左眼用光路中に前記画像表示素子の表示した像から左眼用リレー像を形成するために、少なくとも前記第２１面と前記第２２面とが、光束にパワーを与える曲面形状にて構成されると共に、前記第２１面と前記第２２面とが同一の面形状を有するように構成され、

前記右眼用接眼プリズムが、前記光路振分けプリズムの前記第３１面から射出された右眼用光路の光束をプリズム内に入射させる第１面と、プリズム内で右眼用光路の光束を反射する第２面と、プリズム外に右眼用光路の光束を射出する第３面とを有し、

前記左眼用接眼プリズムが、前記光路振分けプリズムの前記第３２面から射出された左眼用光路の光束をプリズム内に入射させる第１面と、プリズム内で左眼用光路の光束を反射する第２面と、プリズム外に左眼用光路の光束を射出する第３面とを有し、

少なくとも、前記右眼用接眼プリズムの反射作用面である第２面と、前記左眼用接眼プリズムの反射作用面である第２面とが、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする画像表示装置。

〔１５〕　前記光路振分けプリズムの第３１面と第３２面とが、同一形状の曲面にて構成されていることを特徴とする請求項１４記載の画像表示装置。

〔１６〕　前記光路振分けプリズムの第１面と第２１面と第２２面と第３１面と第３２面とが、それぞれ独立した面としてプリズムの有する光学面を形成し、

前記光路振分けプリズムの第２１面と第２２面と第３１面と第３２面との曲面形状が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項１４又は１５記載の画像表示装置。

〔１７〕　前記光路振分けプリズムの第３１面と第３２面の曲面形状が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項１５記載の画像表示装置。

〔１８〕　前記光路振分けプリズムの第２１面と第２２面と第３１面と第３２面の曲面形状が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項１５記載の画像表示装置。

〔１９〕　前記画像表示素子と前記光路振分けプリズムとが対向配置され、

前記光路振分けプリズムが、前記画像表示素子から前後方向（Ｚ方向）に離れるに従って、前記第１面が配置され、媒質を挟んだ左右の位置に前記第２１面と前記第２２面とが配置され、さらに、前記第３１面と前記第３２面とが配置されるように構成され、

前記右眼用接眼プリズムの第１面と空気間隔を挟んで対向する位置に前記第３１面が配置され、かつ、前記左眼用接眼プリズムの第１面と空気間隔を挟んで対向する位置に前記第３２面が配置されるように構成されていることを特徴とする請求項１５〜１８の何れか１項記載の画像表示装置。

〔２０〕　前記画像表示素子と前記光路振分けプリズムとが対向配置され、

前記光路振分けプリズムが、前記画像表示素子から前後方向（Ｚ方向）に離れるに従って、前記第１面が配置され、媒質を挟んだ左右の位置に前記第３１面と前記第３２面とが配置され、さらに、前記第２１面と前記第２２面とが配置されるように構成され、

前記右眼用接眼プリズムの第１面と空気間隔を挟んで対向する位置に前記第３１面が配置され、かつ、前記左眼用接眼プリズムの第１面と空気間隔を挟んで対向する位置に前記第３２面が配置されるように構成されていることを特徴とする請求項１５～１８の何れか１項記載の画像表示装置。

〔２１〕　前記光路振分けプリズムは、前記第２１面と前記第３２面とが１つの面にて兼用されて構成されると共に、前記第２２面と前記第３１面とが１つの面にて兼用されて構成され、

前記右眼用光路を全反射臨界角よりも大きい角度で前記第２１面と前記第３２面との兼用面に入射させることによって全反射作用によりプリズム内で右眼用光路の光束を反射させ、前記右眼用光路を全反射臨界角よりも小さい角度で前記第２２面と前記第３１面との兼用面に入射させることによって右眼用光路の光束をプリズム外に射出させ、

前記左眼用光路を全反射臨界角よりも大きい角度で第２２面と第３１面との兼用面に入射させることによって全反射作用によりプリズム内で左眼用光路の光束を反射させ、前記左眼用光路を全反射臨界角よりも小さい角度で第２１面と第３２面との兼用面に入射させることによって左眼用光路の光束をプリズム外に射出させ、

前記第２１面と第３２面との兼用面の曲面形状が偏心収差を補正するような回転非対称な曲面形状にて構成され、かつ、前記第２２面と第３１面との兼用面の曲面形状が偏心収差を補正するような回転非対称な曲面形状にて構成されていることを特徴とする請求項１４記載の画像表示装置。

〔２２〕　前記光路振分けプリズムが、第１面から入射した左右の像の光束を第２１面と第２２面とに向けて反射する曲面形状の第４面を有し、

前記光路振分けプリズムの第１面と第２１面と第２２面と第３１面と第３２面と第４面とが、それぞれ独立した面としてプリズムの有する光学面を形成していることを特徴とする請求項１４～１８の何れか１項記載の画像表示装置。

〔２３〕　前記光路振分けプリズムの第４面の曲面形状が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項２２記載の画像表示装置。

〔２４〕　前記画像表示素子と前記光路振分けプリズムとが対向配置され、

前記光路振分けプリズムが、前記画像表示素子から前後方向（Ｚ方向）に離れるに従って、前記第１面が配置され、媒質を挟んだ左右の位置に前記第２１面と前記第２２面とが配置され、媒質を挟んだ左右の位置に前記第３１面と前記第３２面とが配置され、

さらに、前記第１面と媒質を挟んで対向する位置に前記第４面が配置されるように構成され、

前記右眼用接眼プリズムの第１面と空気間隔を挟んで対向する位置に前記第３１面が配置され、かつ、前記左眼用接眼プリズムの第１面と空気間隔を挟んで対向する位置に前記第３２面が配置されるように構成されていることを特徴とする請求項２３記載の画像表示装置。

〔２５〕　前記光路振分けプリズムが、第１面から入射した右眼用光路を第２１面に向けて反射する第４１面と、第１面から入射した左眼用光路を第２２面に向けて反射する第４２面とを有し、

前記光路振分けプリズムの第１面と第２１面と第２２面と第３１面と第３２面と第４１面と第４２面とが、それぞれ独立した面としてプリズムの有する光学面を形成していることを特徴とする請求項１４～１８の何れか１項記載の画像表示装置。

〔２６〕　前記光路振分けプリズムの第４１面と第４２面とが、同一形状の曲面にて構成されていることを特徴とする請求項２５記載の画像表示装置。

〔２７〕　前記光路振分けプリズムの第４１面と第４２面の曲面形状が、偏

心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項２６記載の画像表示装置。

〔２８〕　前記画像表示素子と前記光路振分けプリズムとが対向配置され、

前記光路振分けプリズムが、前記画像表示素子から前後方向（Ｚ方向）に離れるに従って、前記第１面が配置され、媒質を挟んだ左位置に第２１面が、媒質を挟んだ右位置に第２２面が配置され、媒質を挟んだ左位置に第３２面が、媒質を挟んだ右位置に第３１面が配置され、前記第１面と媒質を挟んで対向する位置に第４１面と第４２面とが隣接して配置されるように構成されていることを特徴とする請求項２７記載の画像表示装置。

〔２９〕　前記光路振分けプリズムの前記第１面が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項１４～２８の何れか１項記載の載の画像表示装置。

〔３０〕　前記光路振分けプリズムの有する回転非対称な曲面が、唯一の対称面を備えた自由曲面にて構成されていることを特徴とする請求項１４～１８の何れか１項記載の画像表示装置。

〔３１〕　前記光路振分けプリズムの有する自由曲面が、前記画像表示素子の表示する像中心と瞳中心とを結んだ面（Ｙ－Ｚ平面）を前記唯一の対称面として構成されていることを特徴とする請求項３０記載の画像表示装置。

〔３２〕　前記右眼用接眼プリズムが、前記光路振分けプリズムから射出され前記第１面を透過してプリズム内に入射した光束を全反射臨界角よりも大きい角度で前記第３面に入射させることによって全反射作用によりプリズム内で前記第２面に向けて反射させ、前記第２面で反射した光束を全反射臨界角よりも小さい角度で前記第３面に入射させることによってこの第３面を透過させて光束をプリズム外に射出させるように構成され、

前記左眼用接眼プリズムが、前記光路振分けプリズムから射出され前記第１面を透過してプリズム内に入射した光束を全反射臨界角よりも大きい角度で前記第３面に入射させることによって全反射作用によりプリズム内で前記第２面に向け

て反射させ、前記第2面で反射した光束を全反射臨界角よりも小さい角度で前記第3面に入射させることによってこの第3面を透過させて光束をプリズム外に射出させるように構成されていることを特徴とする請求項１４～１８の何れか１項記載の画像表示装置。

〔３３〕　前記右眼用接眼プリズムが、前記光路振分けプリズムから射出され前記第1面を透過してプリズム内に入射した光束を前記第2面で反射させ、前記第2面で反射した光束を前記第3面を透過させて光束をプリズム外に射出させるように構成され、

前記左眼用接眼プリズムが、前記光路振分けプリズムから射出され前記第1面を透過してプリズム内に入射した光束を前記第2面で反射させ、前記第2面で反射した光束を前記第3面を透過させて光束をプリズム外に射出させるように構成されていることを特徴とする請求項１４～１８の何れか１項記載の画像表示装置。

〔３４〕　前記右眼用接眼プリズムが、光束をプリズム内で反射する第4面を有し、

前記右眼用接眼プリズムが、前記光路振分けプリズムから射出され前記第1面を透過してプリズム内に入射した光束を前記第4面で反射し、前記第4面から反射された光束を全反射臨界角よりも大きい角度で前記第3面に入射させることによって全反射作用によりプリズム内で前記第2面に向けて反射させ、前記第2面で反射した光束を全反射臨界角よりも小さい角度で前記第3面に入射させることによってこの第3面を透過させて光束をプリズム外に射出させるように構成され、

前記左眼用接眼プリズムが、光束をプリズム内で反射する第4面を有し、

前記左眼用接眼プリズムが、前記光路振分けプリズムから射出され前記第1面を透過してプリズム内に入射した光束を前記第4面で反射し、前記第4面から反射された光束を全反射臨界角よりも大きい角度で前記第3面に入射させることによって全反射作用によりプリズム内で前記第2面に向けて反射させ、前記第2面で反射した光束を全反射臨界角よりも小さい角度で前記第3面に入射させること

によってこの第３面を透過させて光束をプリズム外に射出させるように構成されていることを特徴とする請求項１４～１８の何れか１項記載の画像表示装置。

〔３５〕　前記右眼用接眼プリズムの第４面が、偏心収差を補正する回転非対称な曲面形状にて構成され、

前記左眼用接眼プリズムの第４面が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項３４記載の画像表示装置。

〔３６〕　前記右眼用接眼プリズムの第１面が、偏心収差を補正する回転非対称な曲面形状にて構成され、

前記左眼用接眼プリズムの第１面が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項１４～１８の何れか１項記載の画像表示装置。

〔３７〕　前記右眼用接眼プリズムの第２面が、偏心収差を補正する回転非対称な曲面形状にて構成され、

前記左眼用接眼プリズムの第２面が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項１４～１８の何れか１項記載の画像表示装置。

〔３８〕　前記右眼用接眼プリズムの第３面が、回転対称非球面にて構成され、

前記左眼用接眼プリズムの前記第３面が、回転対称非球面にて構成されていることを特徴とする請求項１４～１８の何れか１項記載の画像表示装置。

〔３９〕　前記右眼用接眼プリズムの第３面が、偏心収差を補正する回転非対称な曲面形状にて構成され、

前記左眼用接眼プリズムの第３面が、偏心収差を補正する回転非対称な曲面形状にて構成されていることを特徴とする請求項１４～１８の何れか１項記載の画像表示装置。

〔４０〕　前記光路振分けプリズムは、前記右眼用リレー像を前記第３１面よりも光路上観察者の右眼側の位置に形成すると共に、前記左眼用リレー像を前記第３２面よりも光路上観察者の左眼側の位置に形成するように、全体として正

のパワーを有するように構成されていることを特徴とする請求項１４～１８の何れか１項記載の画像表示装置。

〔４１〕　前記光路振分けプリズムは、前記右眼用リレー像を前記第３１面と前記右眼用接眼プリズムの第１面との間の位置に形成すると共に、前記左眼用リレー像を前記第３２面と前記左眼用接眼プリズムの第１面との間の位置に形成するように構成されていることを特徴とする請求項４０記載の画像表示装置。

〔４２〕　前記光路振分けプリズムの第２１面からの右眼用光路の表示光の反射角α、及び、前記光路振分けプリズムの第２２面からの左眼用光路の表示光の反射角αが次の条件を満たすことを特徴とする請求項１４～１８の何れか１項記載の画像表示装置。

$$33^\circ \leqq \alpha \leqq 70^\circ \qquad \cdots (1)$$

〔４３〕　右眼用射出瞳と左眼用射出瞳の中心間を結んだ線分の中心を通りその線分に垂直な平面と、前記光路振分けプリズムの第２１面に右眼用光路の光軸が入射する点における前記第２１面の接平面とがなす角β、及び、右眼用射出瞳と左眼用射出瞳の中心間を結んだ線分の中心を通りその線分に垂直な平面と、前記光路振分けプリズムの第２２面に左眼用光路の光軸が入射する点における前記第２２面の接平面とがなす角βが次の条件を満たすことを特徴とする請求項１４～１８の何れか１項記載の画像表示装置。

$$13^\circ \leqq \beta \leqq 24^\circ \qquad \cdots (2)$$

〔４４〕　瞳側から逆光線追跡した場合に、右眼用射出瞳中心を通る右側最大画角の光線と前記右眼用接眼プリズムの第３面とが交わる点と、左眼用射出瞳中心を通る左側最大画角の光線と前記左眼用接眼プリズムの第３面とが交わる点との間隔を横幅Ｌとし、また、左右の射出瞳中心を通る全画角内の光線束の中、前記右眼用接眼プリズムあるいは前記左眼用接眼プリズムの第３面を透過あるいは反射する点の中で最も左右の射出瞳側に近い点と、前記画像表示素子の表示面とのその表示面に垂直な方向の距離を奥行Ｄとし、横幅Ｌと奥行Ｄとの比Ｄ／Ｌが次の条件を満たすことを特徴とする請求項１４～１８の何れか１項記載の画像表示装置。

０．３≦Ｄ／Ｌ≦０．５　　　　　　　　　　　　　　　　　・・・（３）

〔４５〕　前記右眼用接眼プリズムの第２面が半透過反射面にて構成され、その第２面の外側に右眼用シースループリズムを配置し、

前記左眼用接眼プリズムの第２面が半透過反射面にて構成され、その第２面の外側に左眼用シースループリズムを配置したことを特徴とする請求項１４～１８の何れか１項記載の画像表示装置。

〔４６〕　観察者が観察する画像を表示する画像表示素子と、前記画像を右眼用光路と左眼用光路とに振分ける光路振分けプリズムと、前記光路振分けプリズムの右側に配置された右眼用接眼プリズムと、前記光路振分けプリズムの左側に配置された左眼用接眼プリズムとを有し、

前記光路振分けプリズムが、前記画像表示素子に対向配置され前記画像表示素子から射出された表示光束をプリズム内部に入射させる第１面と、前記第１面から入射した前記右眼用光路を反射する第２１面と、前記第１面から入射した前記左眼用光路を反射する第２２面と、前記右眼用光路の光束をプリズム外に射出させる第３１面と、前記左眼用光路の光束をプリズム外に射出させる第３２面と、を少なくとも有し、

前記光路振分けプリズムは、少なくとも、前記第２１面と、前記第２２面と、前記第３１面と、前記第３２面とが、光束にパワーを与える曲面形状にて構成されると共に、前記第２１面と前記第２２面とが同一の面形状を有し、前記第３１面と前記第３２面とが同一の面形状を有するように構成され、

前記画像表示素子が、光源からの光束を反射することによって画像を表示する反射型画像表示素子から構成され、

前記光路振分けプリズムの有する、前記第２１面と前記２２面とが共に、半透過反射面若しくは部分透過部分反射面の何れかにて構成され、

前記第２１面のプリズム媒質とは反対側の位置に左眼用の光路を形成するための左眼用照明光源を配置し、前記第２２面のプリズム媒質とは反対側の位置に右眼用の光路を形成するための右眼用照明光源を配置して構成されていることを特徴とする画像表示装置。

〔４７〕　観察者が観察する画像を表示する画像表示素子と、前記画像を右眼用光路と左眼用光路とに振分ける光路振分けプリズムと、前記光路振分けプリズムの右側に配置された右眼用接眼プリズムと、前記光路振分けプリズムの左側に配置された左眼用接眼プリズムとを有し、

前記光路振分けプリズムが、前記画像表示素子に対向配置され前記画像表示素子から射出された表示光束をプリズム内部に入射させる第1面と、前記第1面と媒質を挟んで対向配置され前記第1面から入射した左右の像の光束を異なった方向に反射させ右眼用光路と左眼用光路とに振り分ける第4面と、前記第4面から反射された前記右眼用光路を反射する第２１面と、前記第4面から反射した前記左眼用光路を反射する第２２面と、前記右眼用光路の光束をプリズム外に射出させる第３１面と、前記左眼用光路の光束をプリズム外に射出させる第３２面と、を少なくとも有し、

前記光路振分けプリズムは、少なくとも、前記第２１面と、前記第２２面と、前記第３１面と、前記第３２面と、前記第4面とが、光束にパワーを与える曲面形状にて構成されると共に、前記第２１面と前記第２２面とが同一の面形状を有し、前記第３１面と前記第３２面とが同一の面形状を有するように構成され、

前記画像表示素子が、光源からの光束を反射することによって画像を表示する反射型画像表示素子から構成され、

前記光路振分けプリズムの有する前記第4面が、半透過反射面若しくは部分透過部分反射面の何れかにて構成され、

前記第4面のプリズム媒質とは反対側の位置に、左眼用の光路を形成するための左眼用照明光源と、右眼用の光路を形成するための右眼用照明光源とを配置して構成されていることを特徴とする画像表示装置。

〔４８〕　観察者が観察する画像を表示する画像表示素子と、前記画像を右眼用光路と左眼用光路とに振分ける光路振分けプリズムと、前記光路振分けプリズムの右側に配置された右眼用接眼プリズムと、前記光路振分けプリズムの左側に配置された左眼用接眼プリズムとを有し、

前記光路振分けプリズムが、前記画像表示素子に対向配置され前記画像表示素

子から射出された表示光束をプリズム内部に入射させる第１面と、前記右眼用光路を全反射臨界角よりも大きい角度で光学面に入射させることによって全反射作用によりプリズム内で右眼用光路の光束を反射させかつ前記左眼用光路を全反射臨界角よりも小さい角度で光学面に入射させることによって左眼用光路の光束をプリズム外に射出させる第２面と、前記左眼用光路を全反射臨界角よりも大きい角度で光学面に入射させることによって全反射作用によりプリズム内で左眼用光路の光束を反射させかつ前記右眼用光路を全反射臨界角よりも小さい角度で光学面に入射させることによって右眼用光路の光束をプリズム外に射出させる第３面と、を有し、

前記画像表示素子と前記第１面との間に表示用光学素子を配置し、

前記光路振分けプリズムは、前記第２面と前記第３面とが光束にパワーを与える同一形状の曲面にて構成され、かつ、前記第２面と前記第３面とをプリズム媒質を挟んで対向するように配置し、

前記画像表示素子が、光源からの光束を透過することによって画像を表示する透過型画像表示素子から構成され、

前記画像表示素子の前記表示用光学素子とは反対側の位置に、左眼用の光路を形成するための左眼用照明光源と、右眼用の光路を形成するための右眼用照明光源とを配置して構成されていることを特徴とする画像表示装置。

〔４９〕　前記表示用光学素子が、フレネルレンズから構成されていることを特徴とする請求項４８記載の画像表示装置。

〔５０〕　前記光路振分けプリズムの第２１面と前記第２２面とが共に、透過と反射を強度的に分割するハーフミラーコーティングにて構成されていることを特徴とする請求項４６記載の画像表示装置。

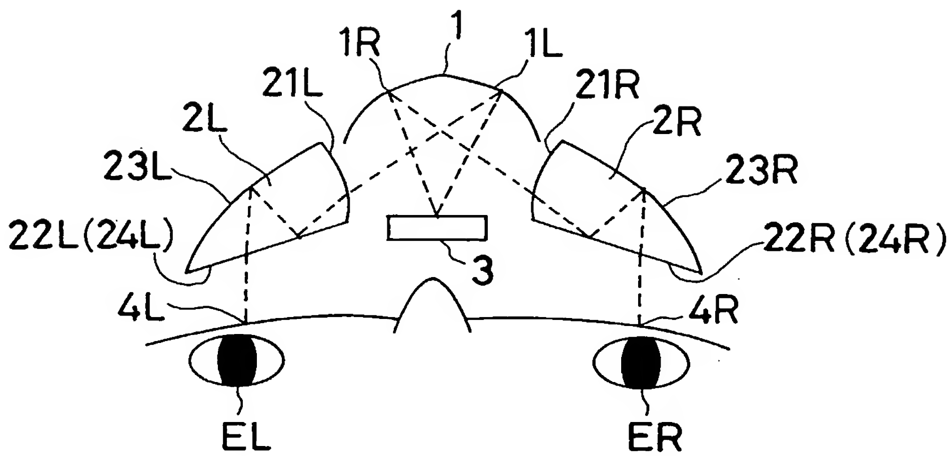
〔５１〕　前記光路振分けプリズムの第２１面と前記第２２面とが共に、反射ミラー面内に透過孔を設けたミラーコーティングにて構成されていることを特徴とする請求項４６記載の画像表示装置。

〔５２〕　前記光路振分けプリズムの第４面が、透過と反射を強度的に分割するハーフミラーコーティングにて構成されたていることを特徴とする請求項４

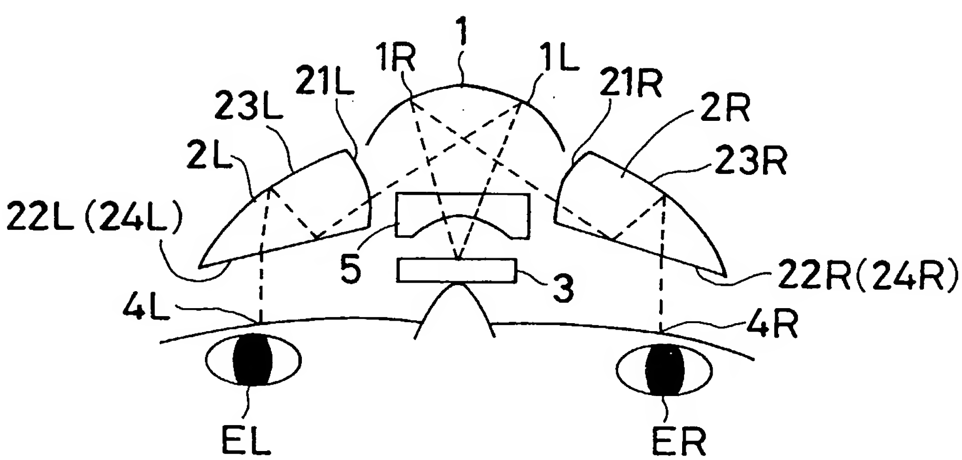
７記載の画像表示装置。

〔５３〕　前記光路振分けプリズムの第４面が、反射ミラー面内に透過孔を設けたミラーコーティングにて構成されていることを特徴とする請求項４７記載の画像表示装置。

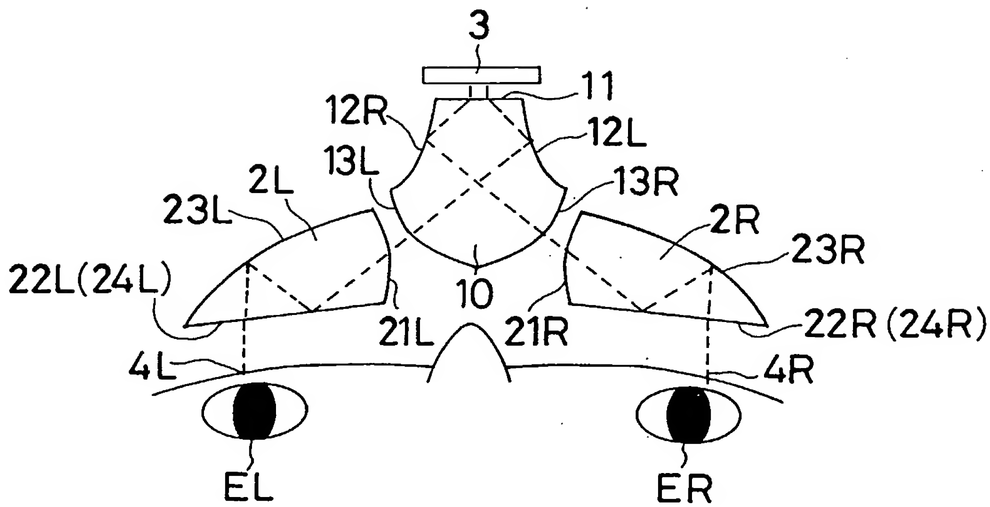
第１図


1
1R
1L
21L
21R
2L
2R
23L
23R
22L(24L)
22R(24R)
3
4L
4R
EL
ER

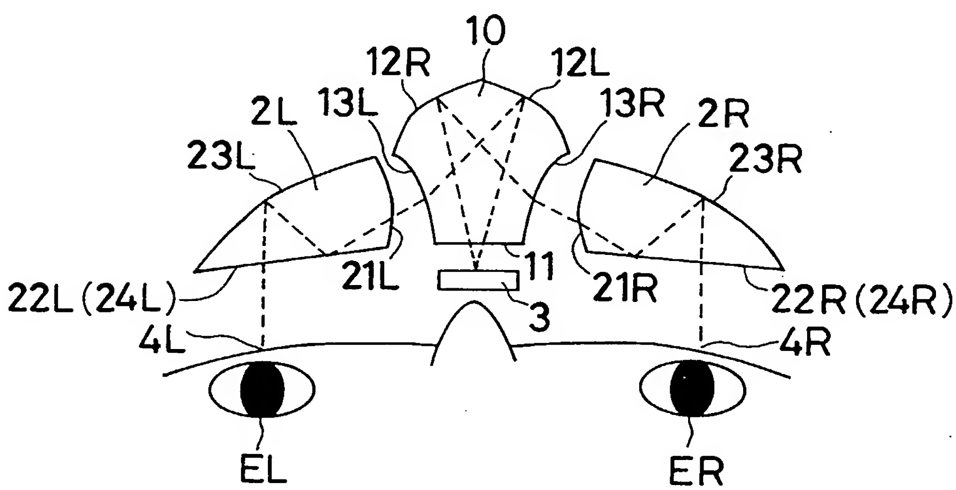
第２図


1
1R
1L
21L
21R
23L
2R
2L
23R
22L(24L)
5
3
22R(24R)
4L
4R
EL
ER

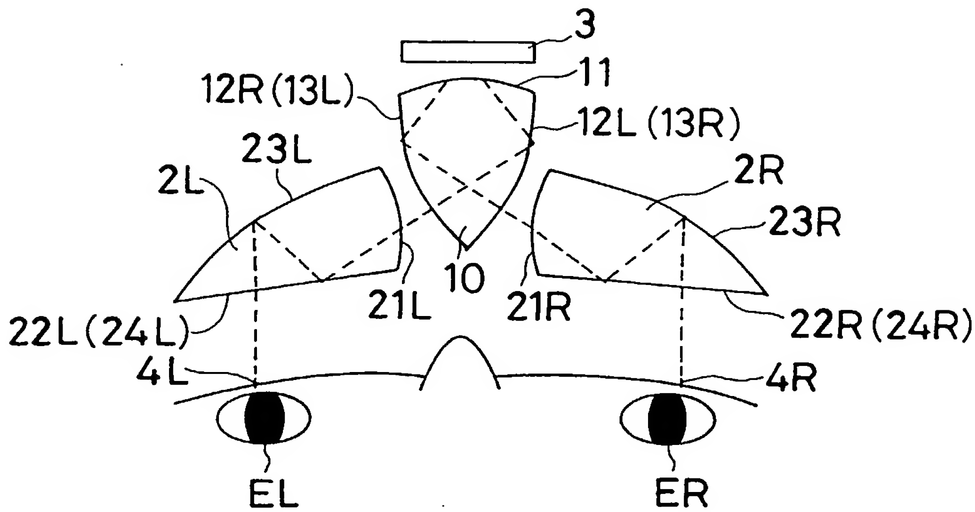
第３図


3
11
12R
12L
13L
13R
2L
2R
23L
23R
22L(24L)
22R(24R)
10
21L
21R
4L
4R
EL
ER

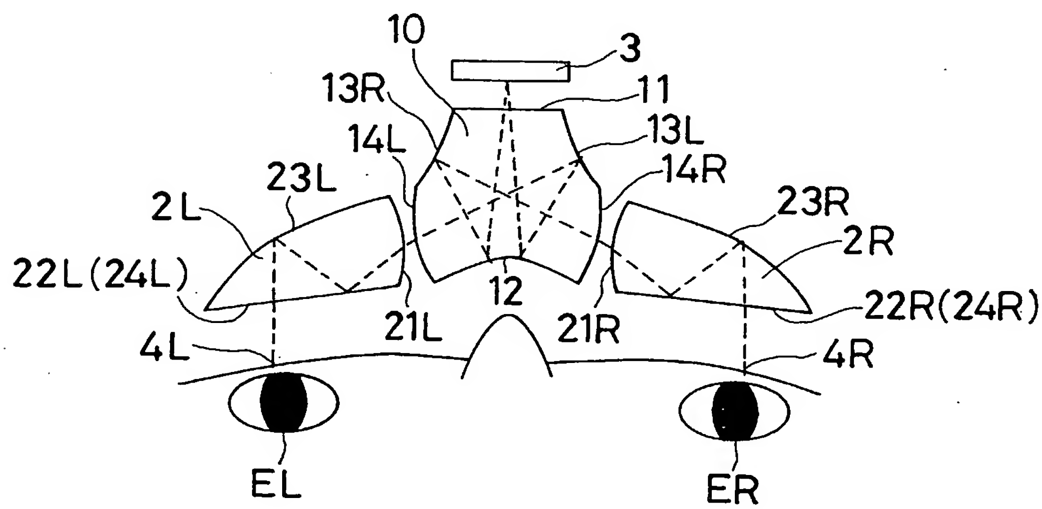
第４図


10
12R
12L
2L
13L
13R
2R
23L
23R
21L
11
21R
22L(24L)
22R(24R)
3
4L
4R
EL
ER

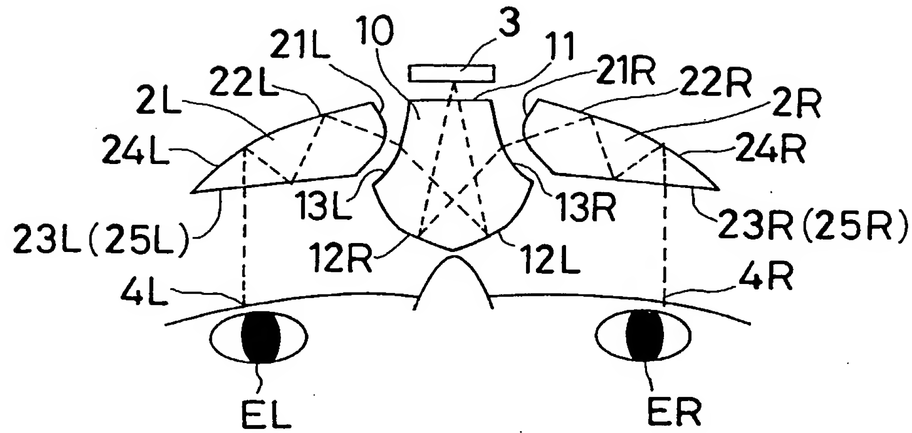
第5図


3
11
12R(13L)
12L(13R)
23L
2L
2R
23R
10
21L
21R
22L(24L)
22R(24R)
4L
4R
EL
ER

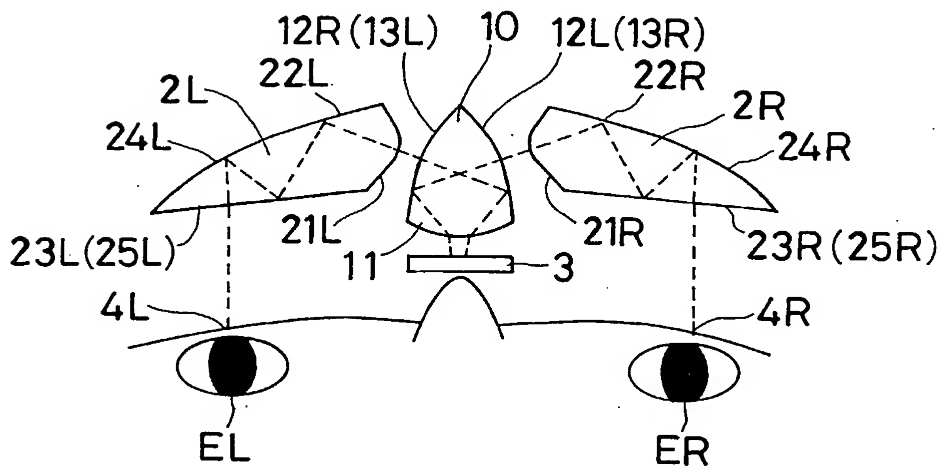
第6図


10
3
13R
11
14L
13L
14R
23L
23R
2L
2R
22L(24L)
12
22R(24R)
21L
21R
4L
4R
EL
ER

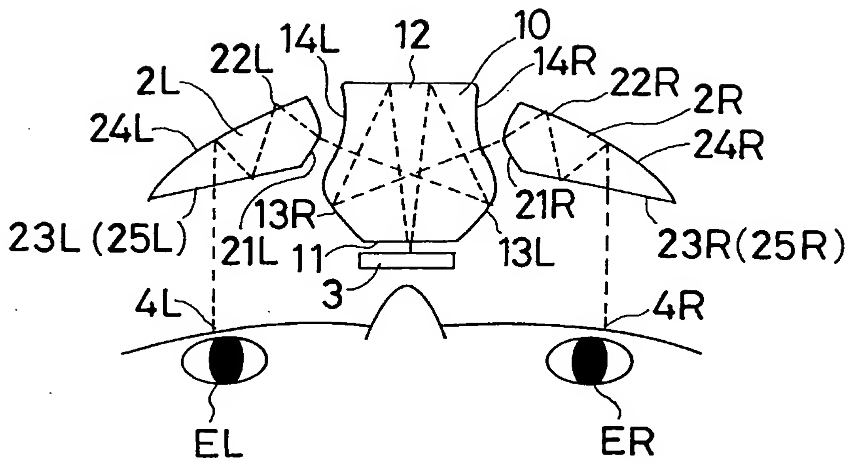
第７図


3
10
11
21L
21R
22L
22R
2L
2R
24L
24R
13L
13R
23L(25L)
23R(25R)
12R
12L
4L
4R
EL
ER

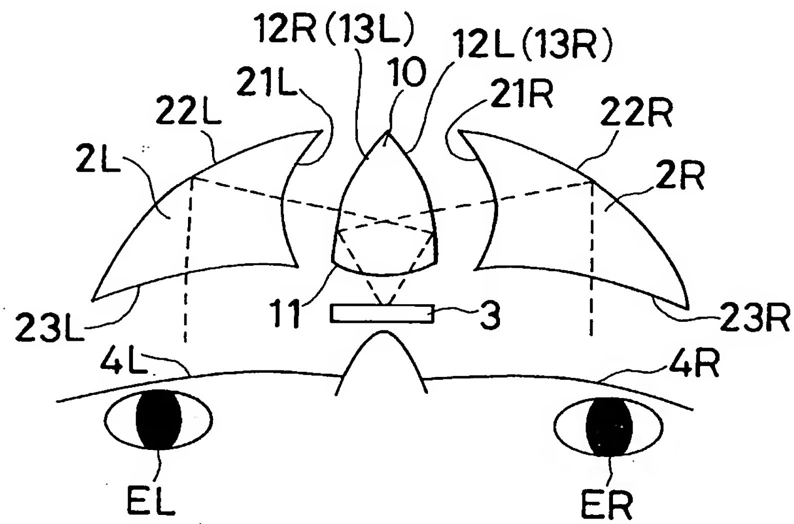
第８図


12R(13L)
10
12L(13R)
22L
22R
2L
2R
24L
24R
21L
21R
23L(25L)
23R(25R)
11
3
4L
4R
EL
ER

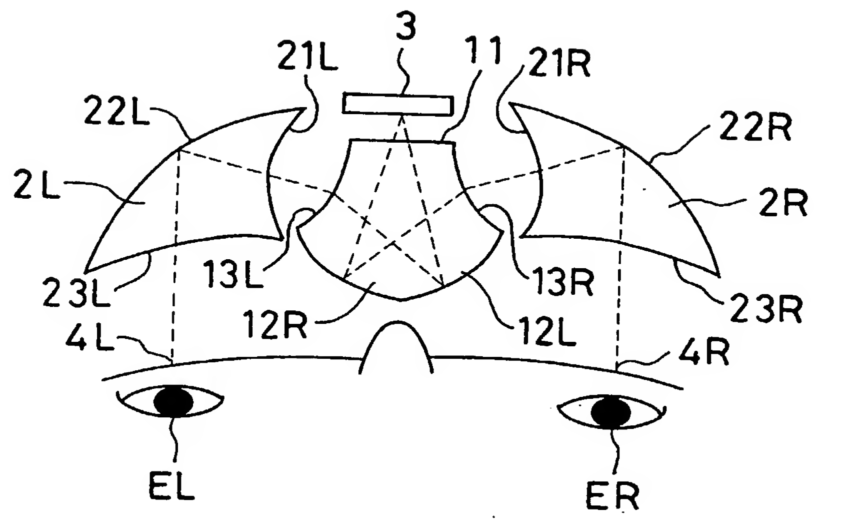
第９図


10
12
14L
14R
22L
22R
2L
2R
24L
24R
21R
13R
23L (25L)
21L
11
13L
23R(25R)
3
4L
4R
EL
ER

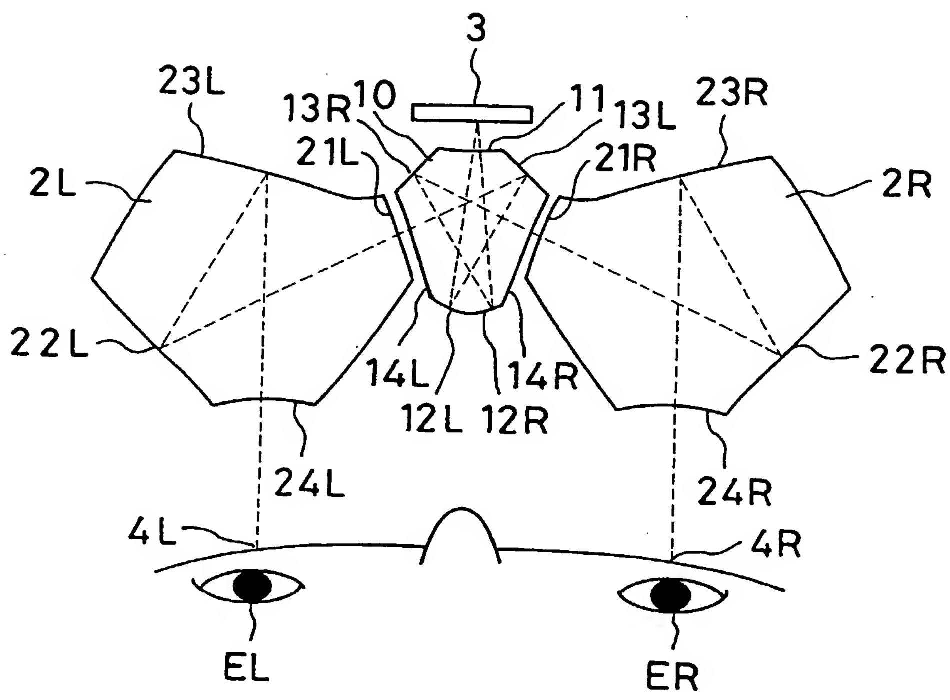
第１０図


12R (13L)
12L (13R)
10
21L
21R
22L
22R
2L
2R
11
3
23L
23R
4L
4R
EL
ER

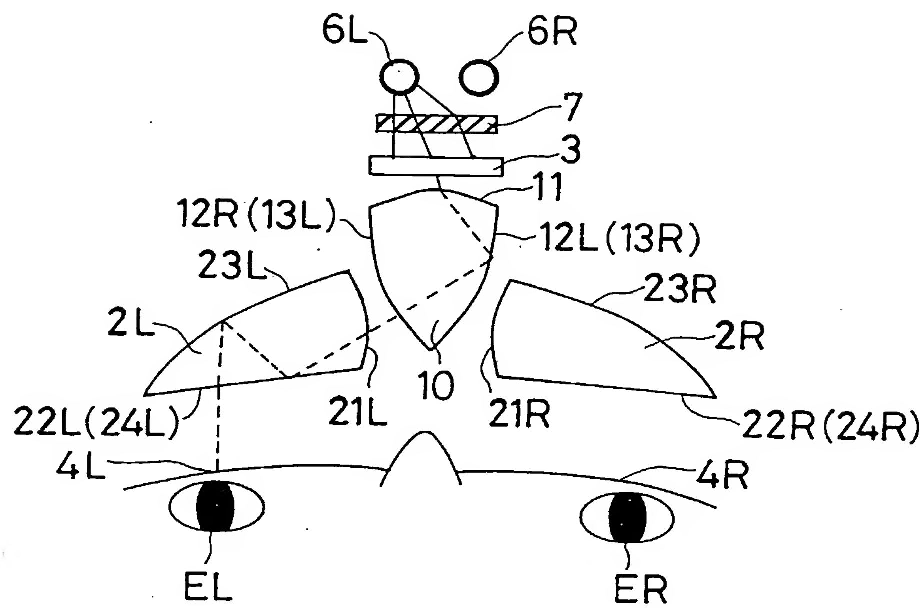
第１１図


3
21L
11
21R
22L
22R
2L
2R
13L
13R
23L
23R
12R
12L
4L
4R
EL
ER

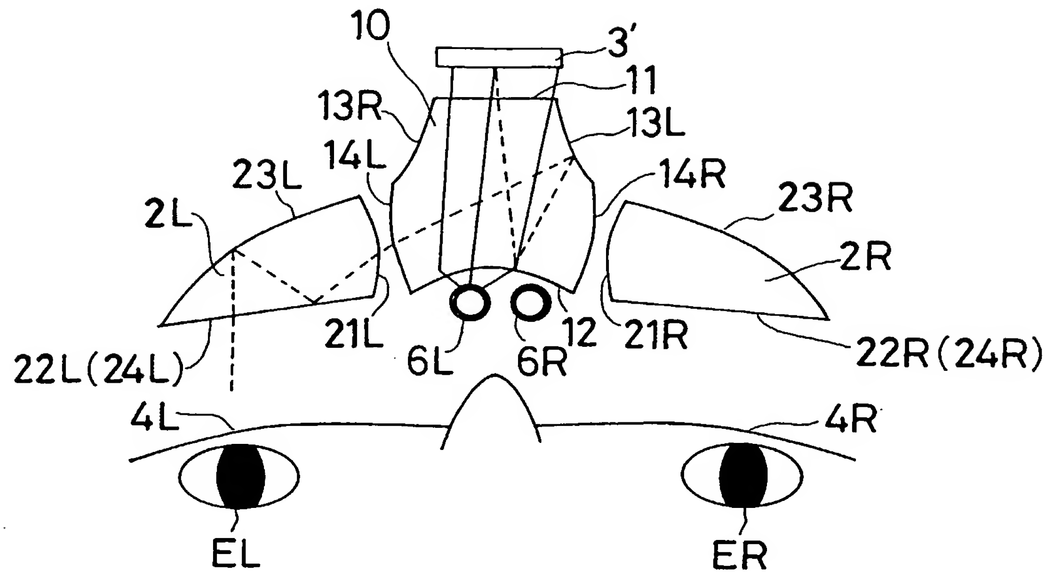
第１２図


3
23L
13R
10
11
13L
23R
21L
21R
2L
2R
22L
22R
14L
14R
12L
12R
24L
24R
4L
4R
EL
ER

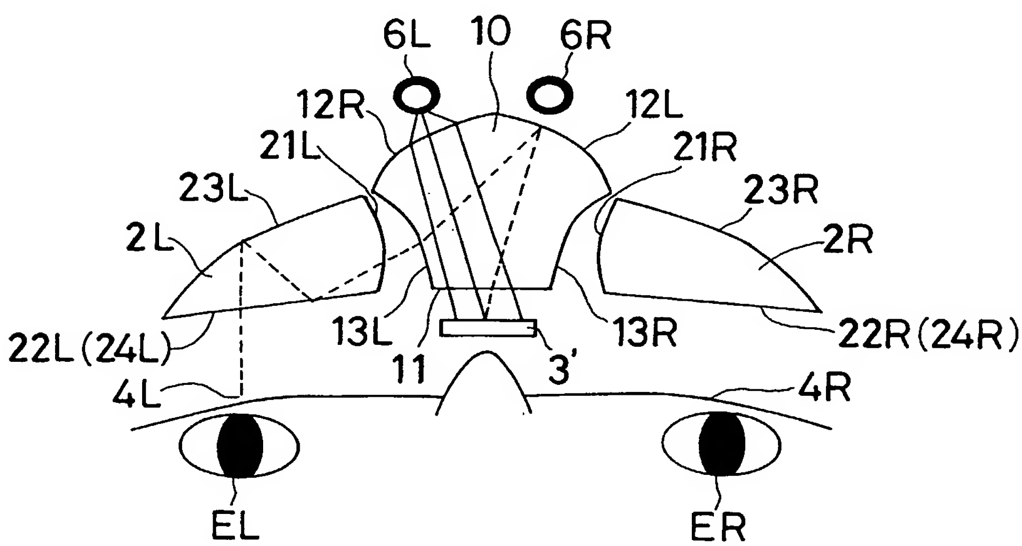
第１３図


6L
6R
7
3
11
12R (13L)
12L (13R)
23L
23R
2L
2R
10
21L
21R
22L (24L)
22R (24R)
4L
4R
EL
ER

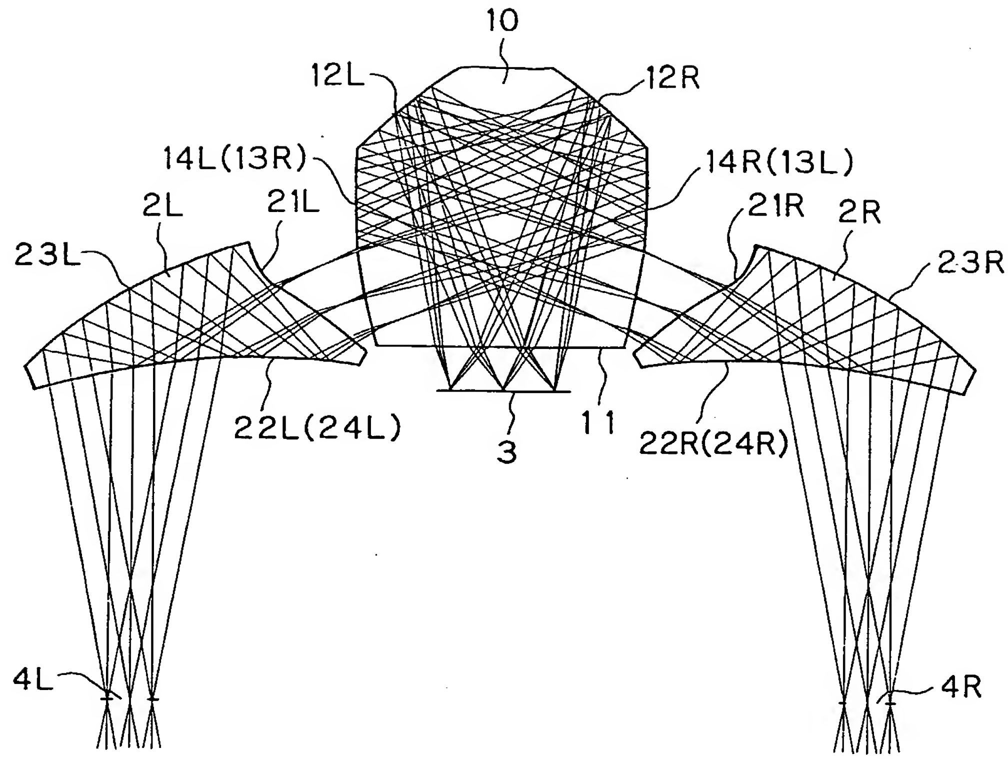
第１４図


10
3'
11
13R
13L
14L
14R
23L
23R
2L
2R
21L
12
21R
6L
6R
22L(24L)
22R(24R)
4L
4R
EL
ER

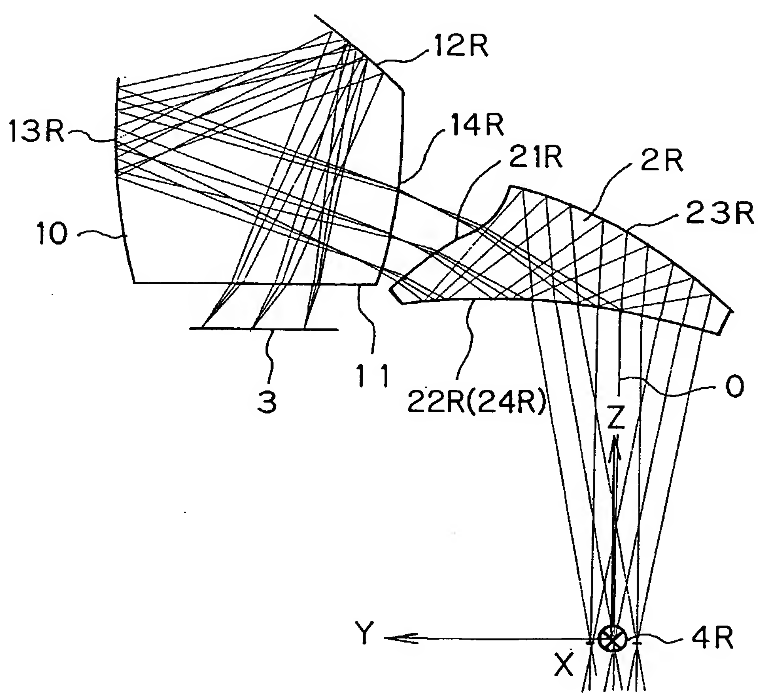
第１５図


6L
10
6R
12R
12L
21L
21R
23L
23R
2L
2R
13L
13R
22L(24L)
22R(24R)
11
3'
4L
4R
EL
ER

第１６図

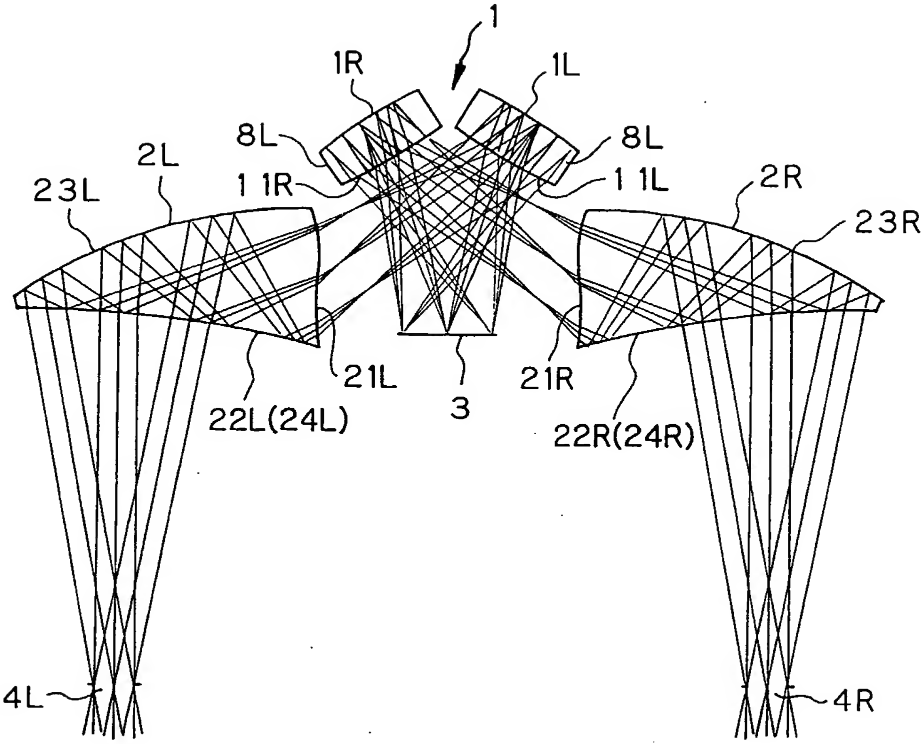

10
12L
12R
14L(13R)
14R(13L)
2L
21L
21R
2R
23L
23R
22L(24L)
3
11
22R(24R)
4L
4R

(a)

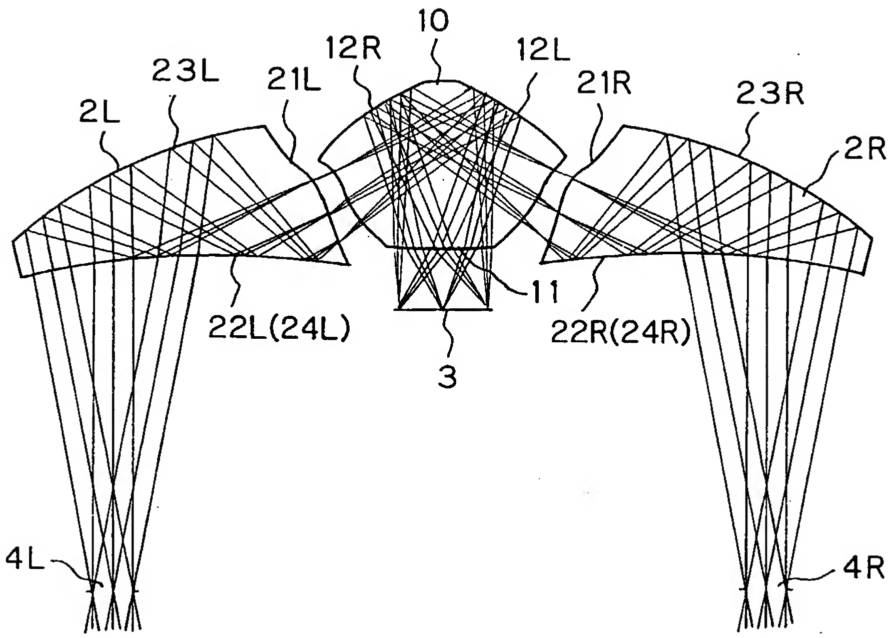

12R
13R
14R
21R
2R
23R
10
3
11
22R(24R)
0
Z
Y
X
4R

(b)

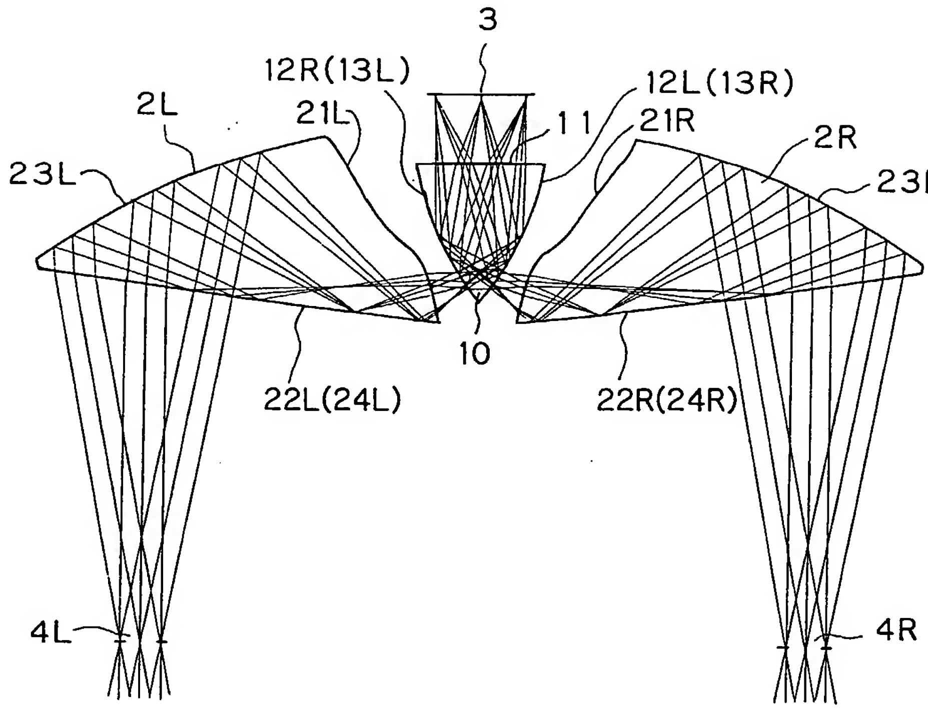
第１７図


1
1R
1L
8L
8L
2L
23L
11R
11L
2R
23R
21L
3
21R
22L(24L)
22R(24R)
4L
4R

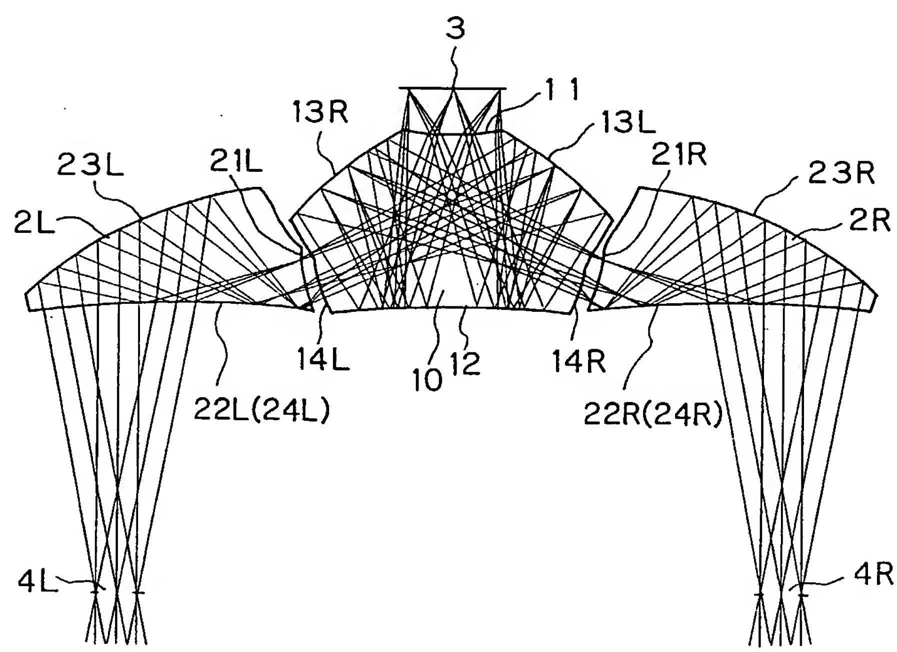
第１８図


10
12R
12L
23L
21L
21R
23R
2L
2R
11
22L(24L)
22R(24R)
3
4L
4R

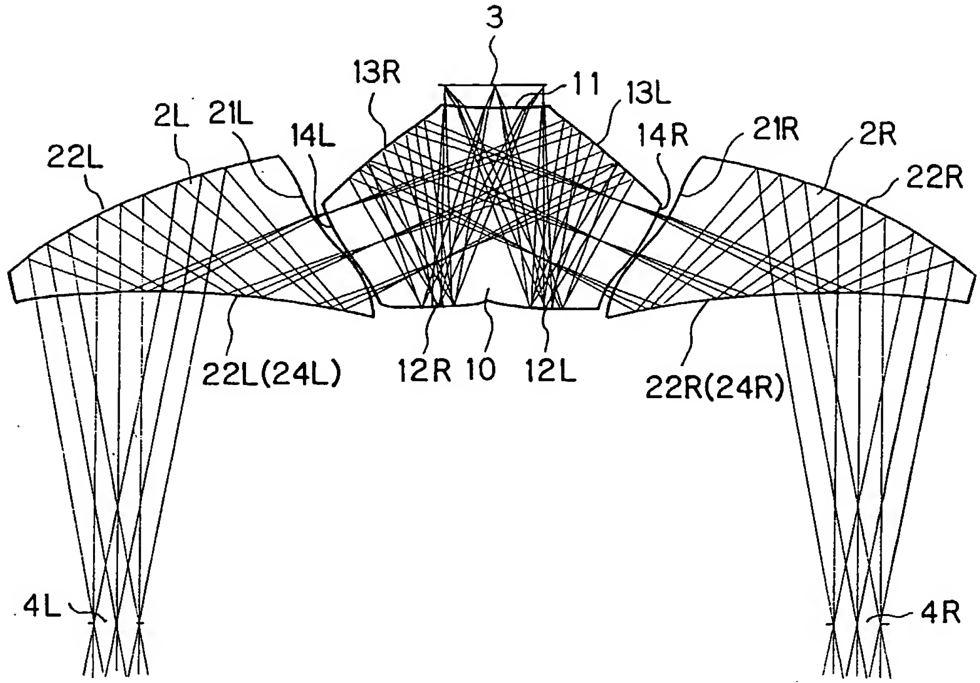
第１９図


3
12R(13L)
12L(13R)
2L
21L
11
21R
2R
23L
23R
10
22L(24L)
22R(24R)
4L
4R

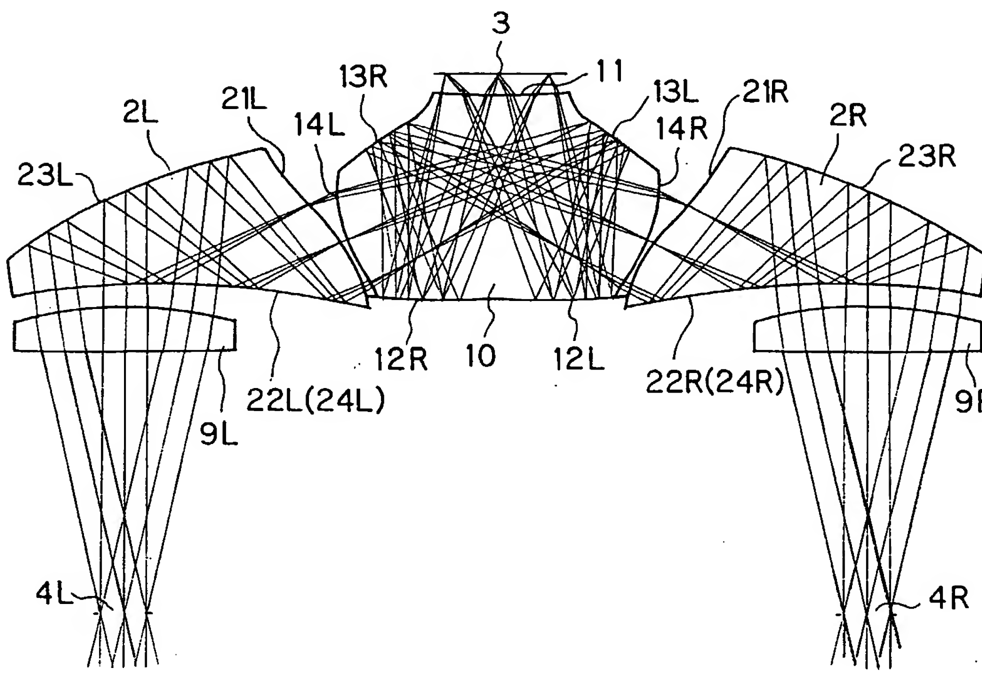
第２０図


3
11
13R
13L
23L
21L
21R
23R
2L
2R
14L
10
12
14R
22L(24L)
22R(24R)
4L
4R

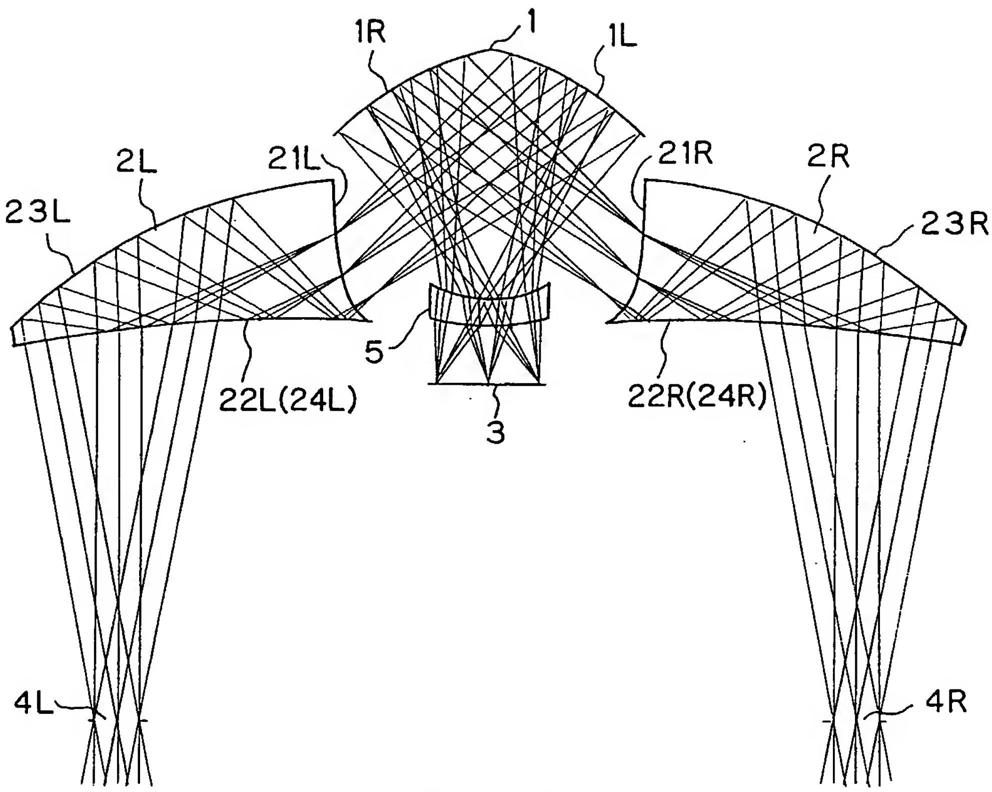
第２１図


3
13R
11
13L
2L
21L
14L
14R
21R
2R
22L
22R
22L(24L)
12R
10
12L
22R(24R)
4L
4R

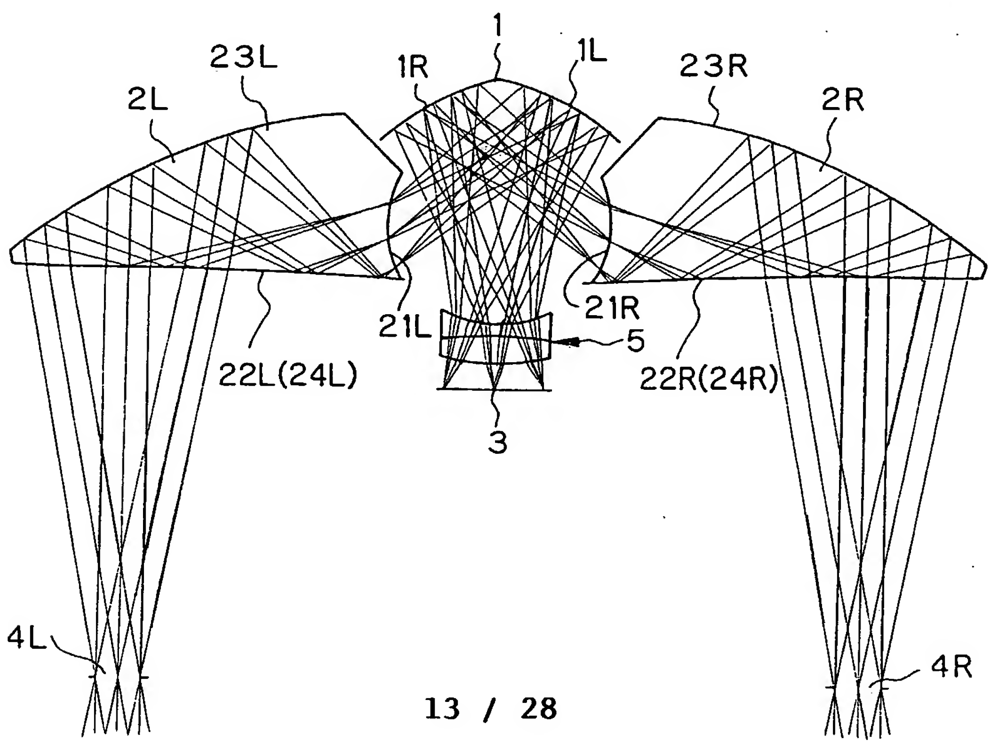
第２２図


3
13R
11
13L
2L
21L
14L
14R
21R
2R
23L
23R
12R
10
12L
22L(24L)
22R(24R)
9L
9R
4L
4R

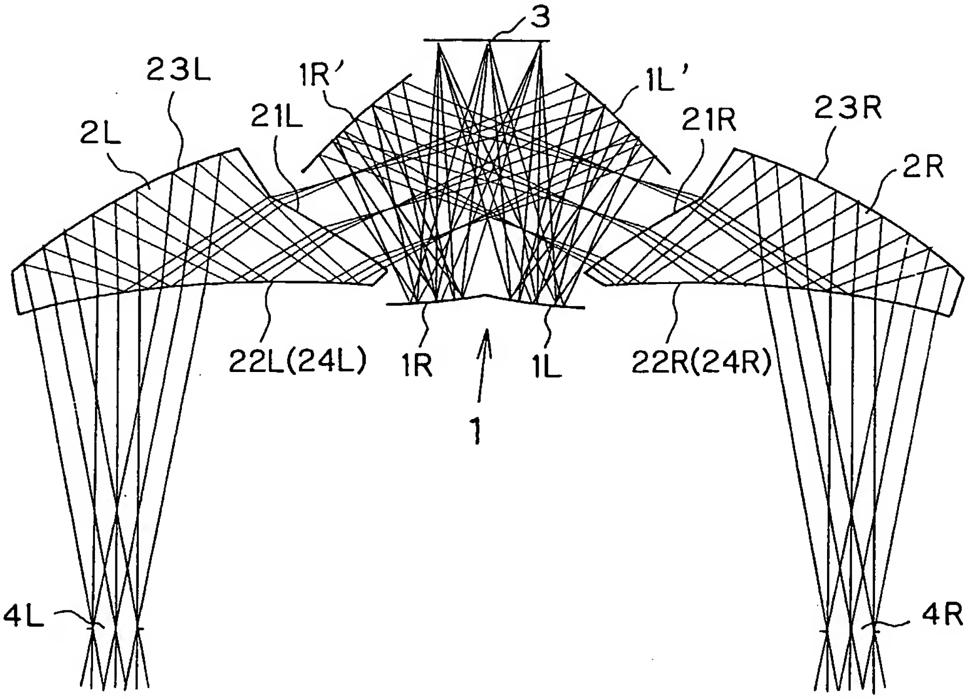
第２３図


1
1R
1L
21L
21R
2L
2R
23L
23R
5
22L(24L)
22R(24R)
3
4L
4R

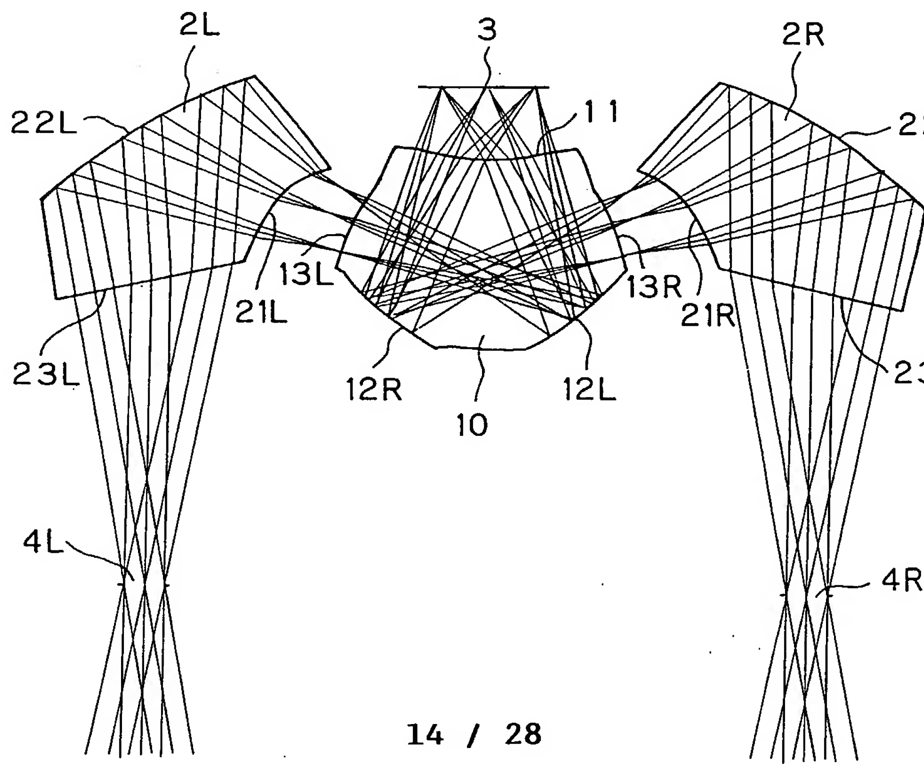
第２４図


1
23L
1R
1L
23R
2L
2R
21R
21L
5
22L(24L)
22R(24R)
3
4L
4R

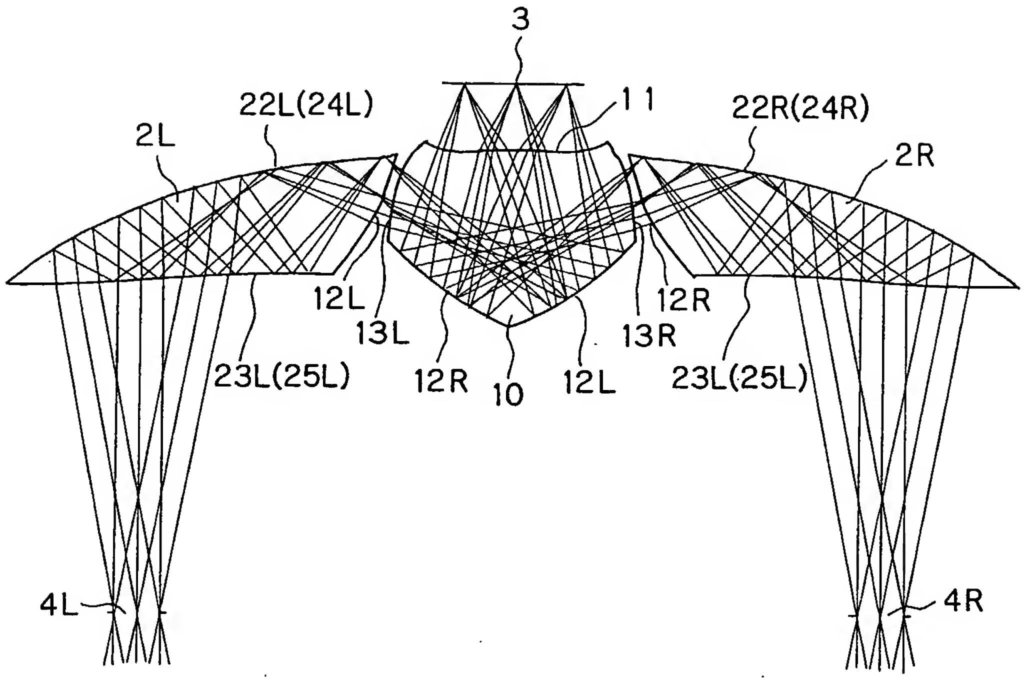
第２５図


3
23L
1R'
1L'
21L
21R
23R
2L
2R
22L(24L)
1R
1L
22R(24R)
1
4L
4R

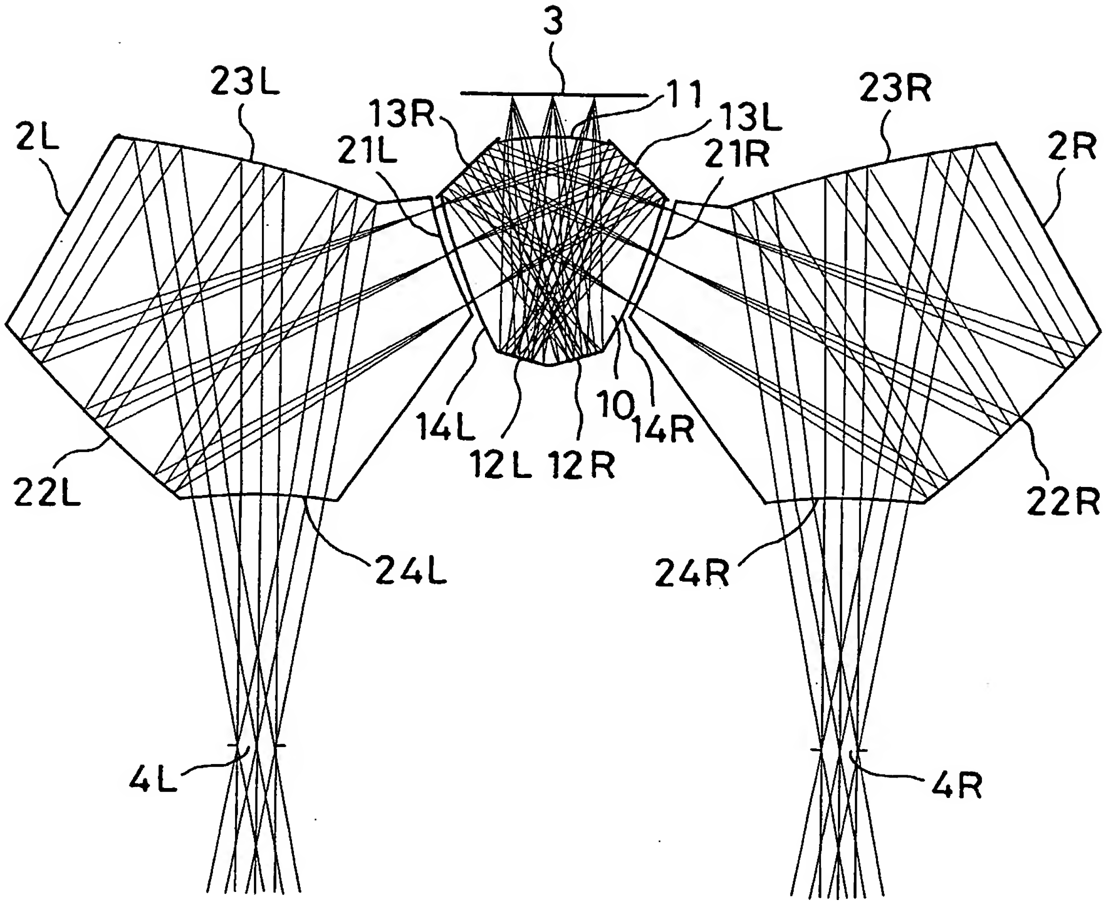
第２６図


2L
3
2R
22L
11
22R
13L
13R
21L
21R
23L
12R
12L
23R
10
4L
4R

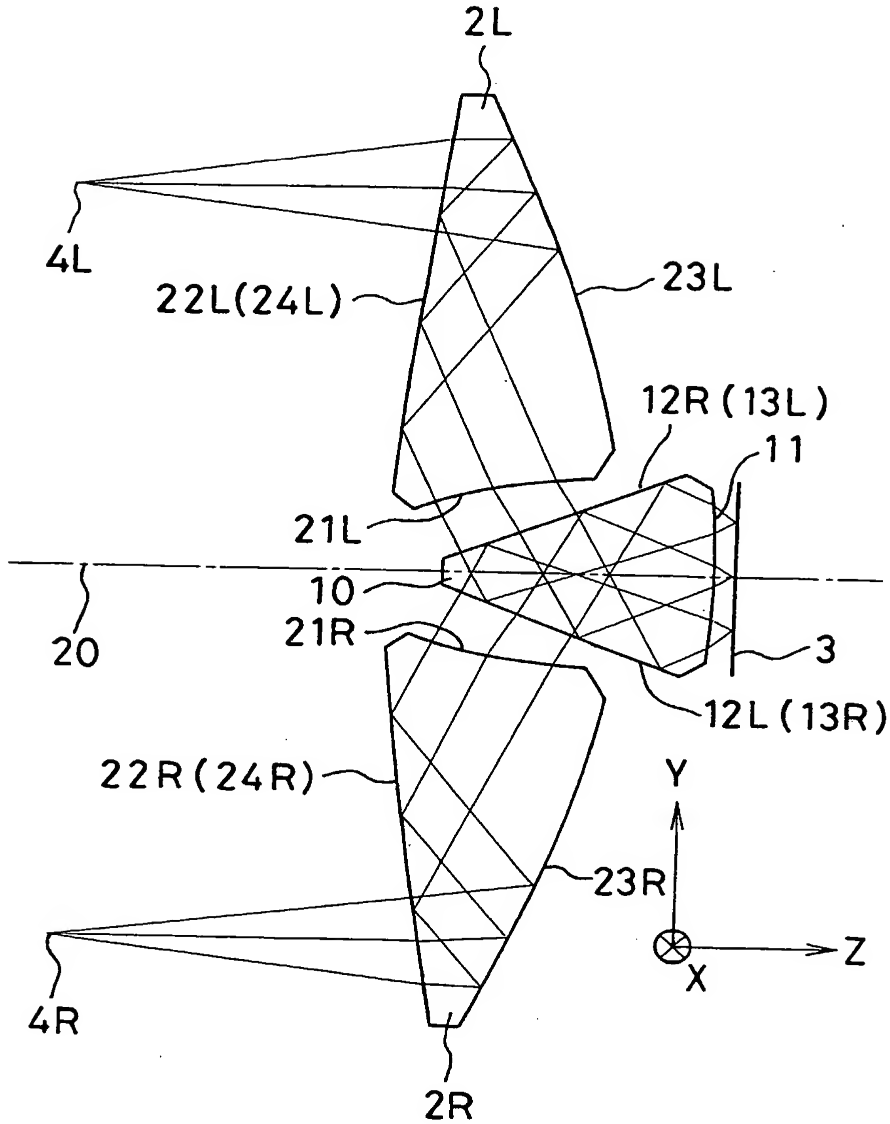
第２７図


3
11
22L(24L)
22R(24R)
2L
2R
12L
13L
12R
13R
23L(25L)
12R
10
12L
23L(25L)
4L
4R

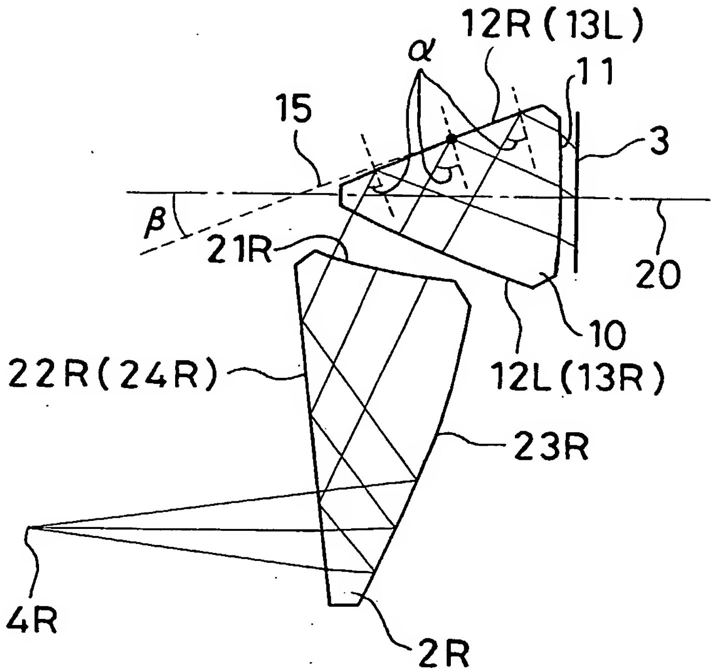
第２８図


3
11
13R
13L
23L
23R
2L
2R
21L
21R
10
14L
14R
12L
12R
22L
22R
24L
24R
4L
4R

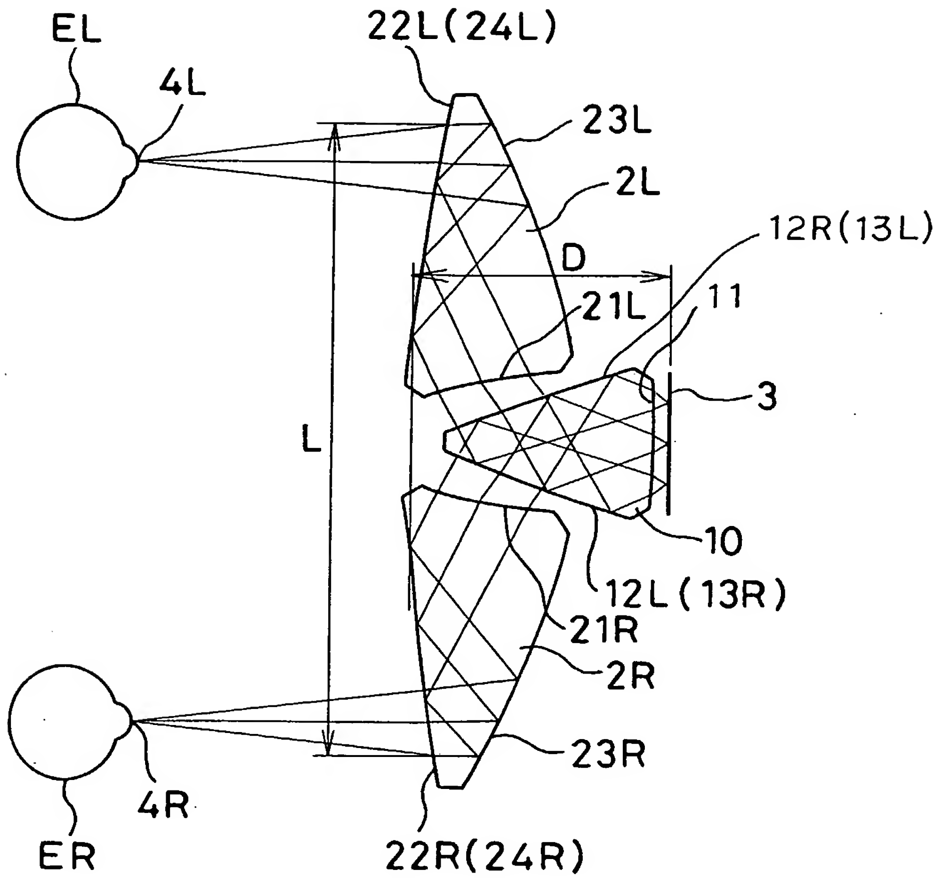
第２９図


2L
4L
22L(24L)
23L
12R(13L)
11
21L
10
20
21R
3
12L(13R)
22R(24R)
Y
23R
Z
X
4R
2R

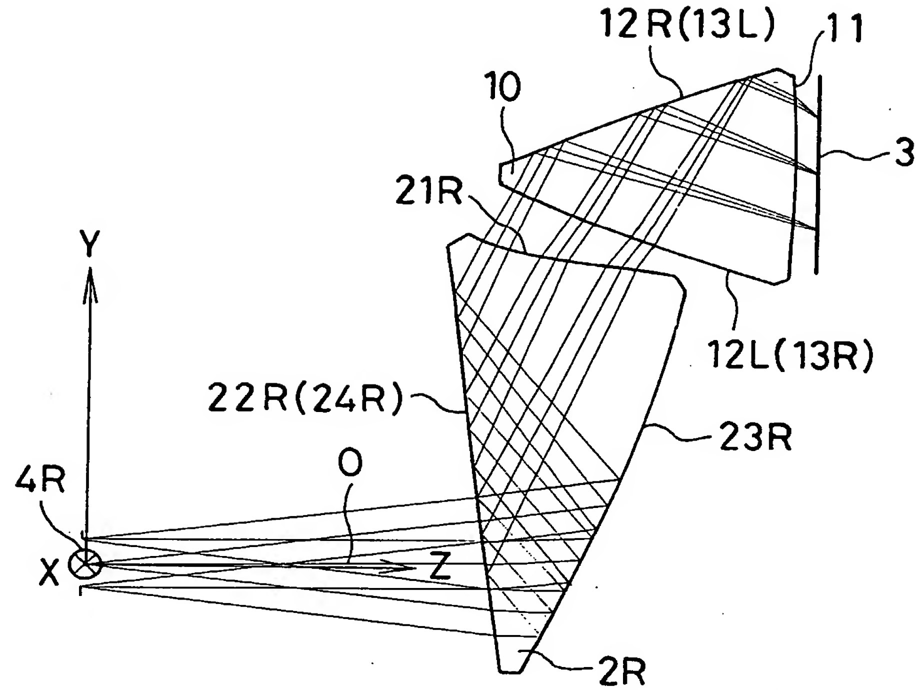
第３０図



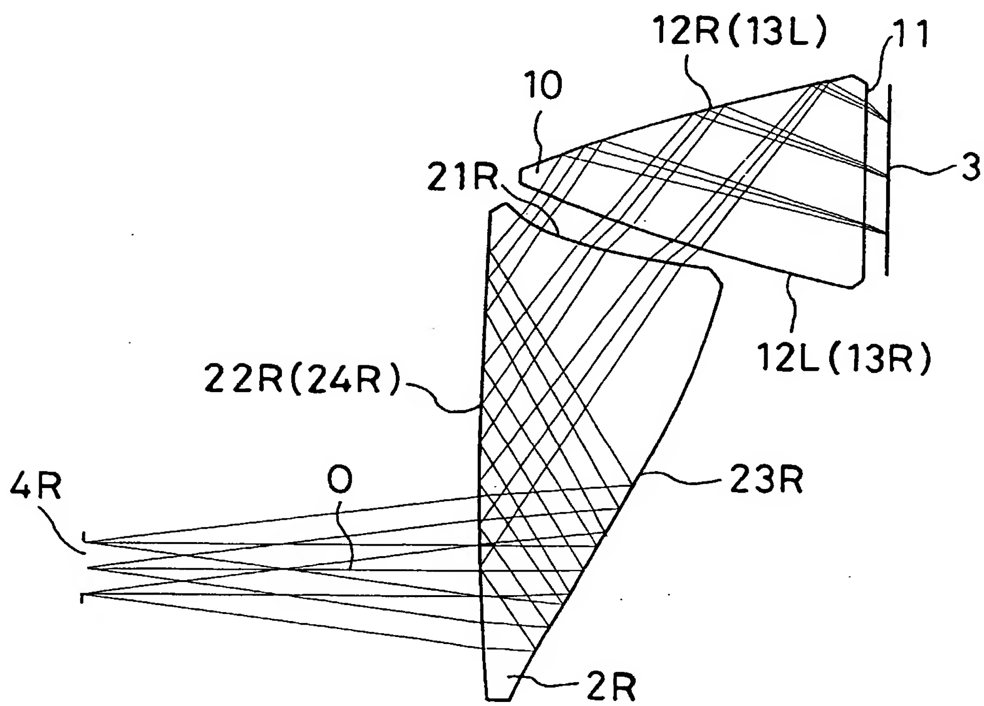
第３１図


EL
4L
22L(24L)
23L
2L
12R(13L)
D
21L
11
3
L
10
12L(13R)
21R
2R
23R
4R
ER
22R(24R)

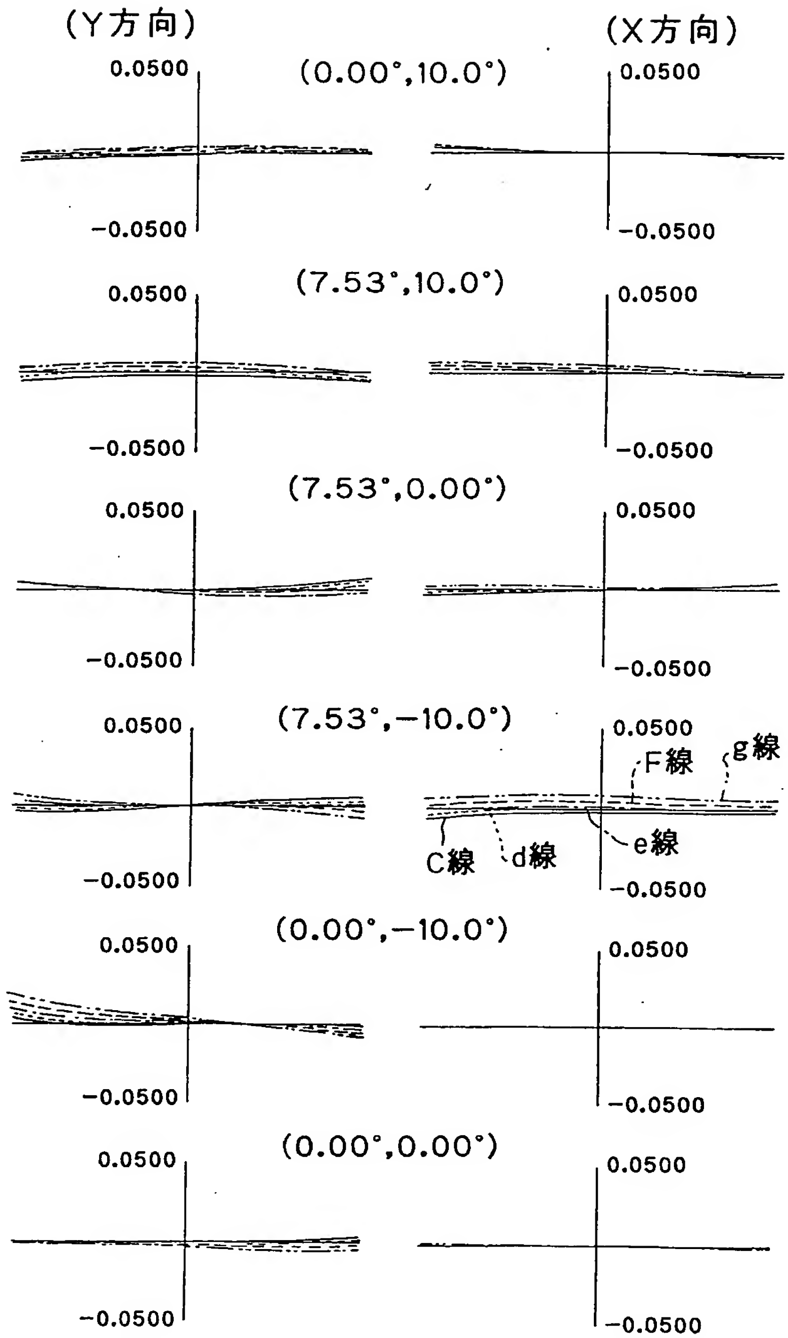
第３２図


12R(13L)
11
10
3
21R
Y
12L(13R)
22R(24R)
23R
4R
O
X
Z
2R

第３３図

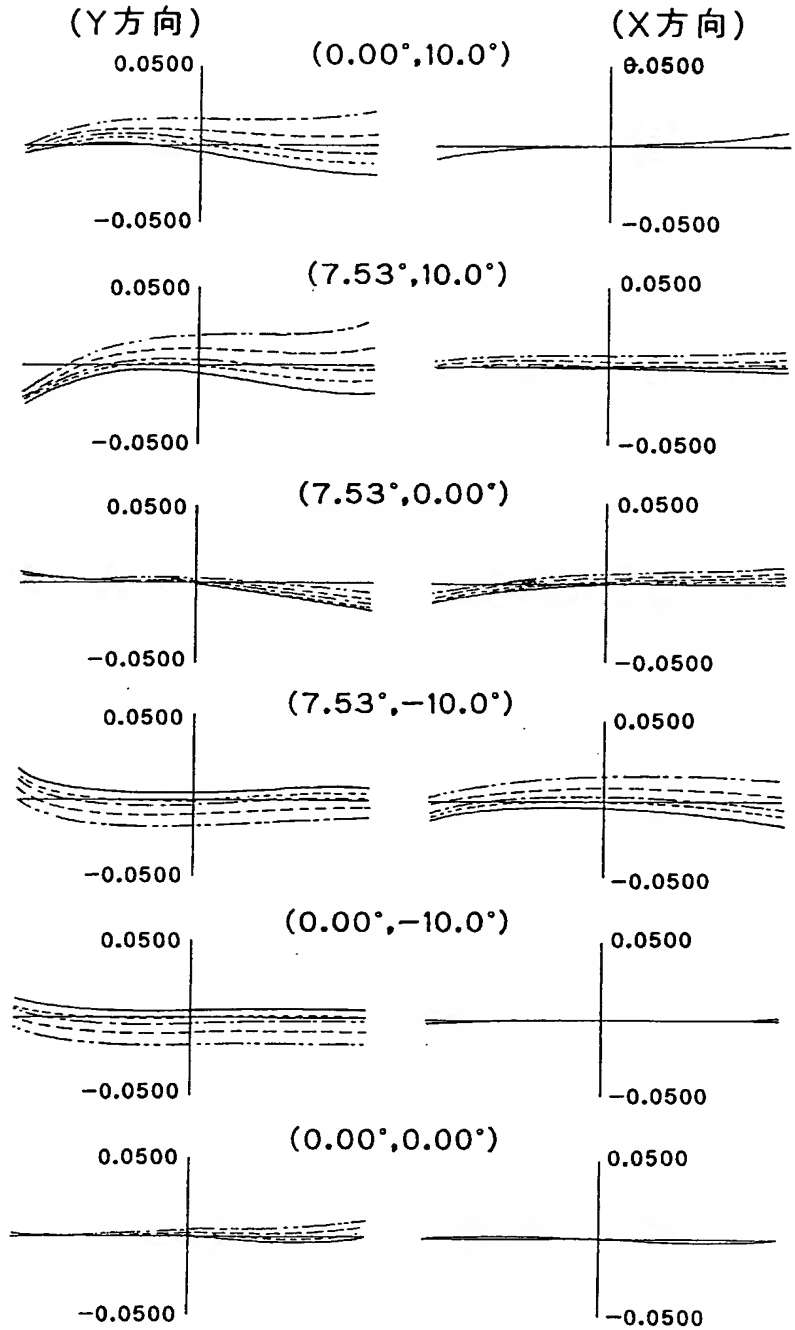

12R(13L)
11
10
3
21R
12L(13R)
22R(24R)
4R
O
23R
2R

第３４図

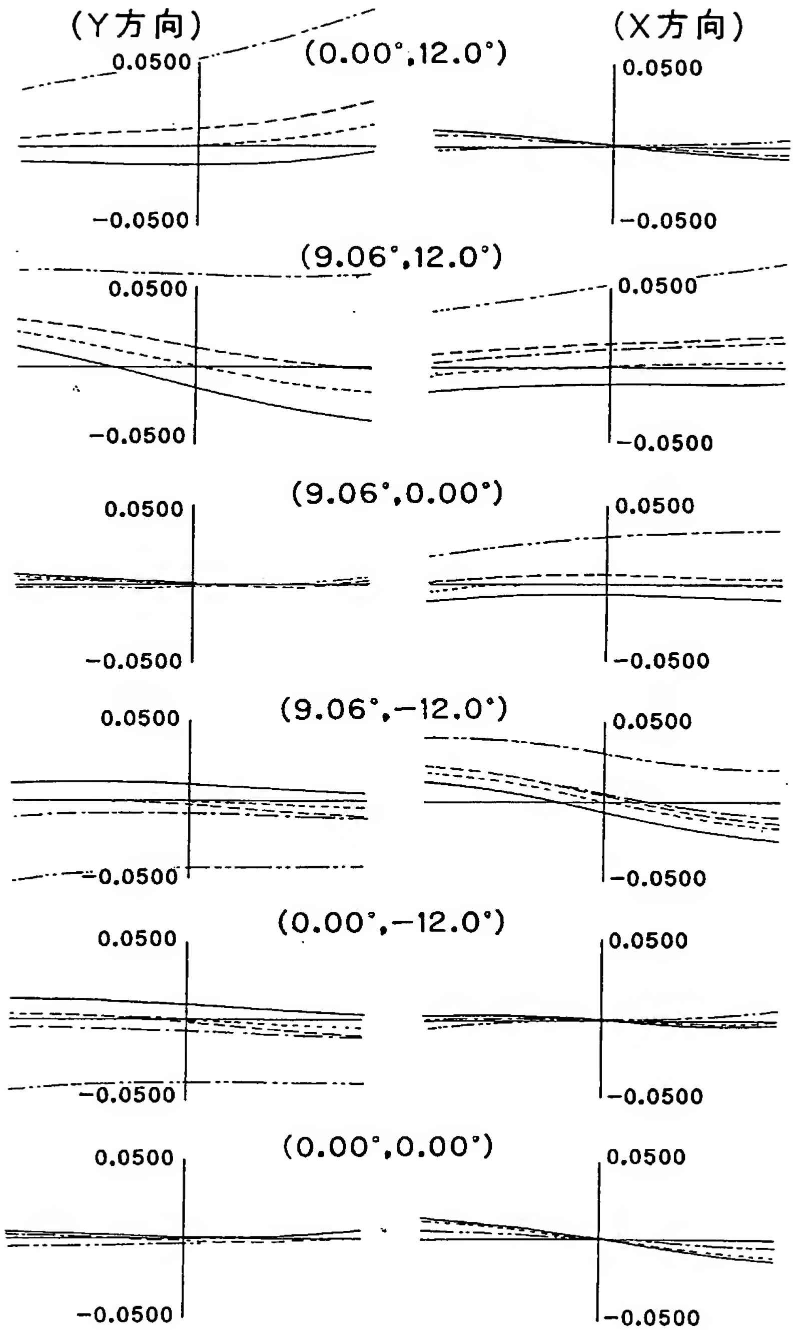


(Y方向)
(X方向)
(0.00°,10.0°)
(7.53°,10.0°)
(7.53°,0.00°)
(7.53°,−10.0°)
(0.00°,−10.0°)
(0.00°,0.00°)
0.0500
−0.0500
F線
g線
C線
d線
e線

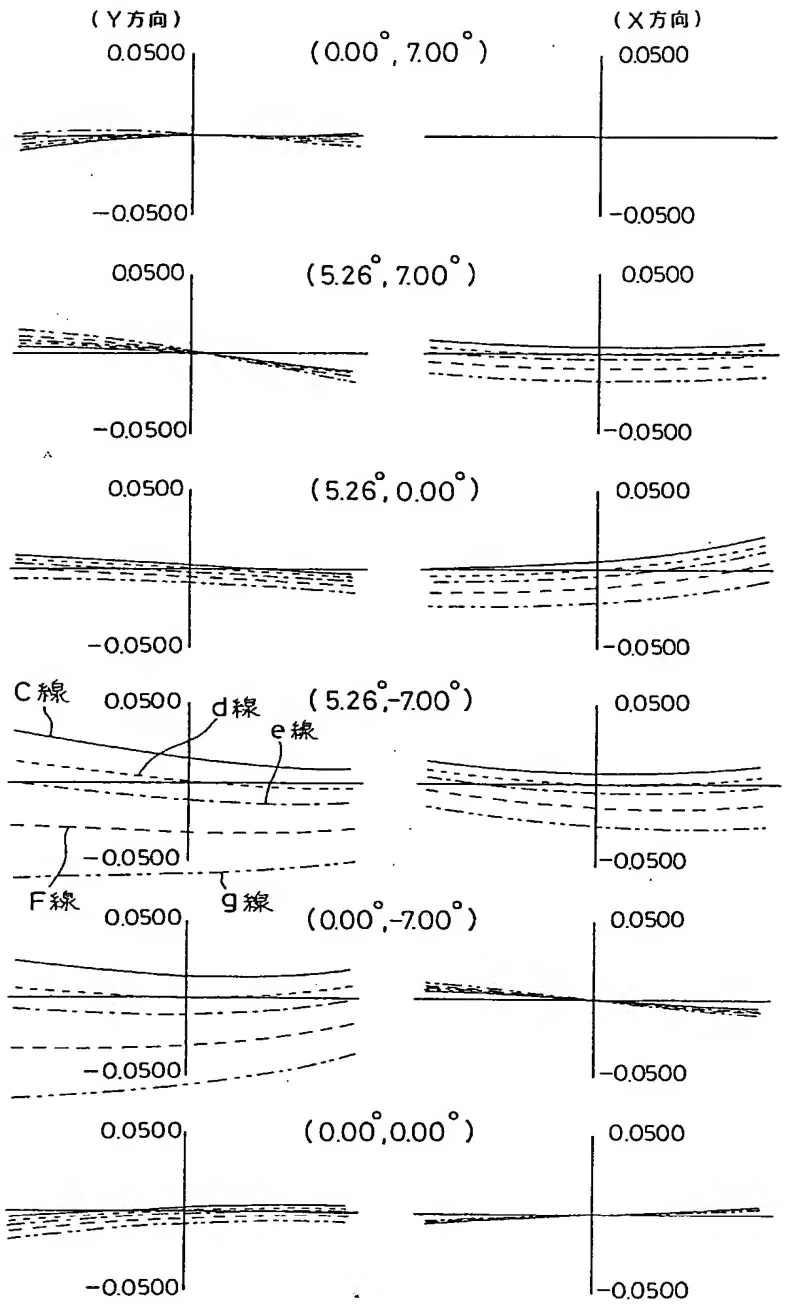
第３５図


(Y方向)
(X方向)
(0.00°,10.0°)
(7.53°,10.0°)
(7.53°,0.00°)
(7.53°,−10.0°)
(0.00°,−10.0°)
(0.00°,0.00°)
0.0500
−0.0500

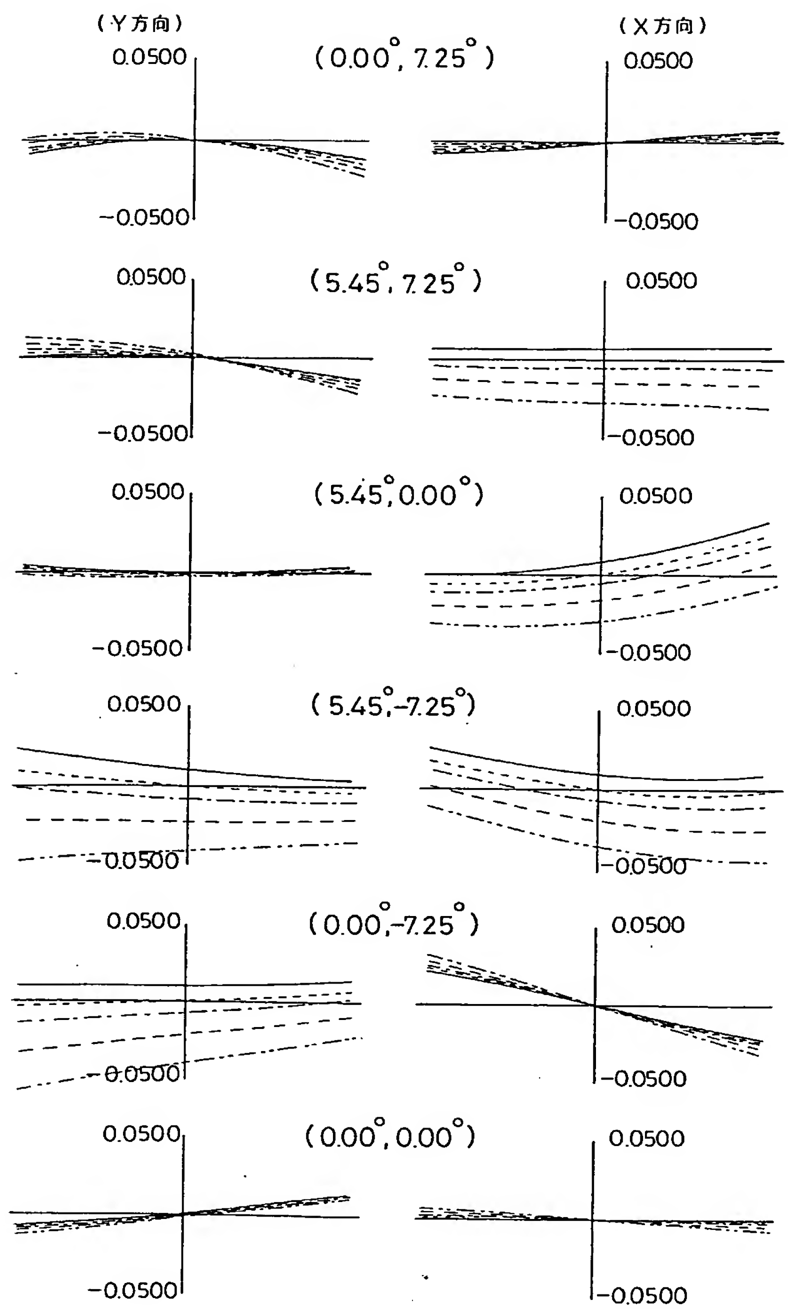
第３６図


(Y方向)
(X方向)
(0.00°,12.0°)
(9.06°,12.0°)
(9.06°,0.00°)
(9.06°,−12.0°)
(0.00°,−12.0°)
(0.00°,0.00°)
0.0500
−0.0500

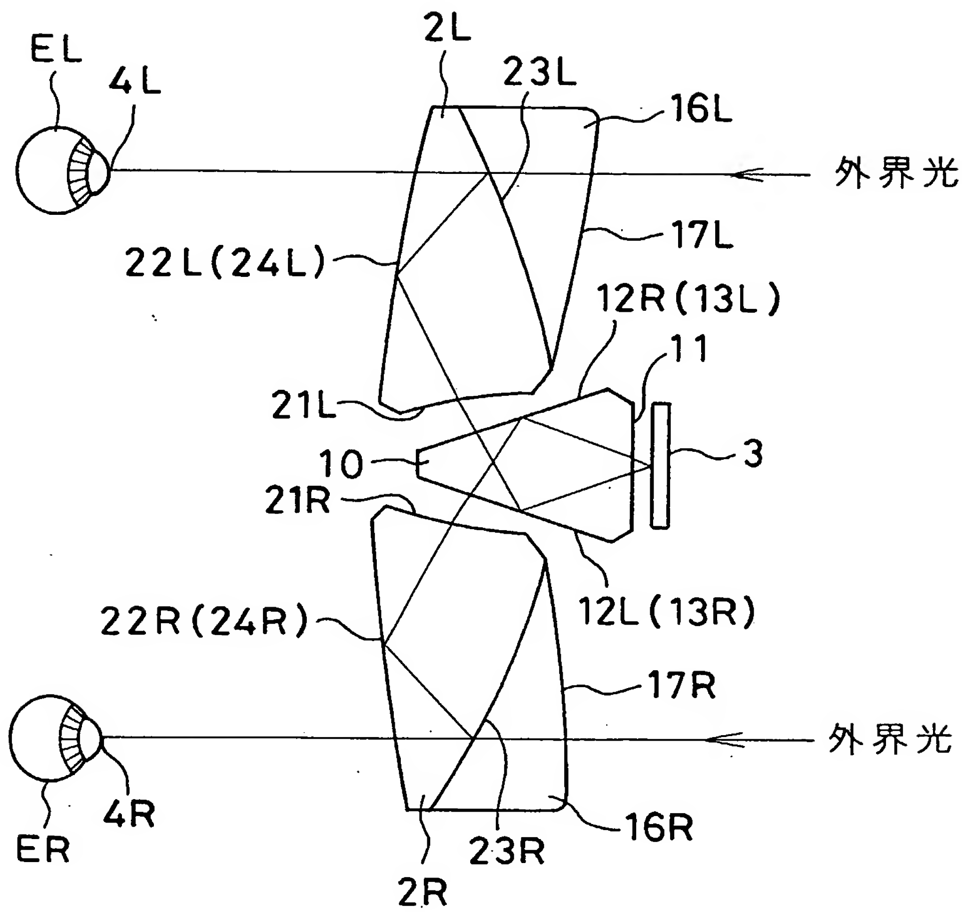
第３７図


(Y方向)
(X方向)
(0.00°, 7.00°)
(5.26°, 7.00°)
(5.26°, 0.00°)
(5.26°,-7.00°)
(0.00°,-7.00°)
(0.00°,0.00°)
0.0500
-0.0500
C線
d線
e線
F線
g線

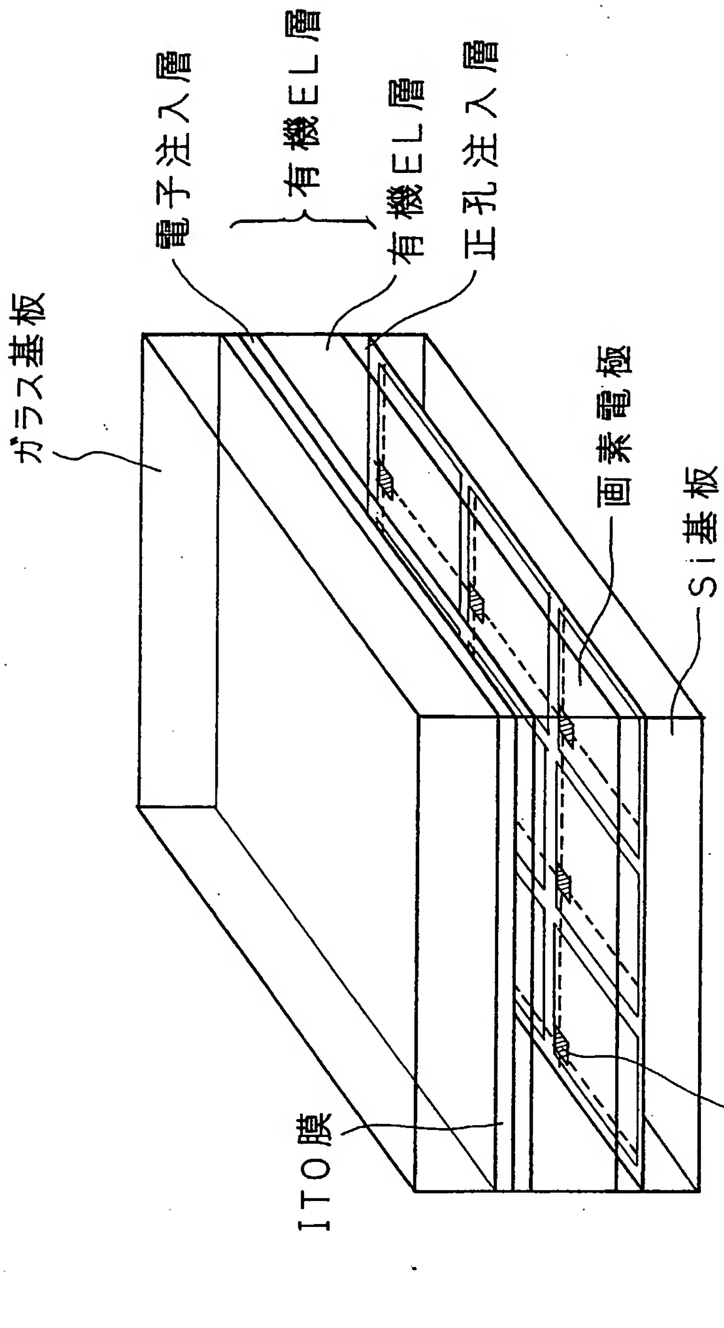
第３８図


（Y方向）
（X方向）
(0.00°, 7.25°)
(5.45°, 7.25°)
(5.45°, 0.00°)
(5.45°, -7.25°)
(0.00°, -7.25°)
(0.00°, 0.00°)
0.0500
-0.0500

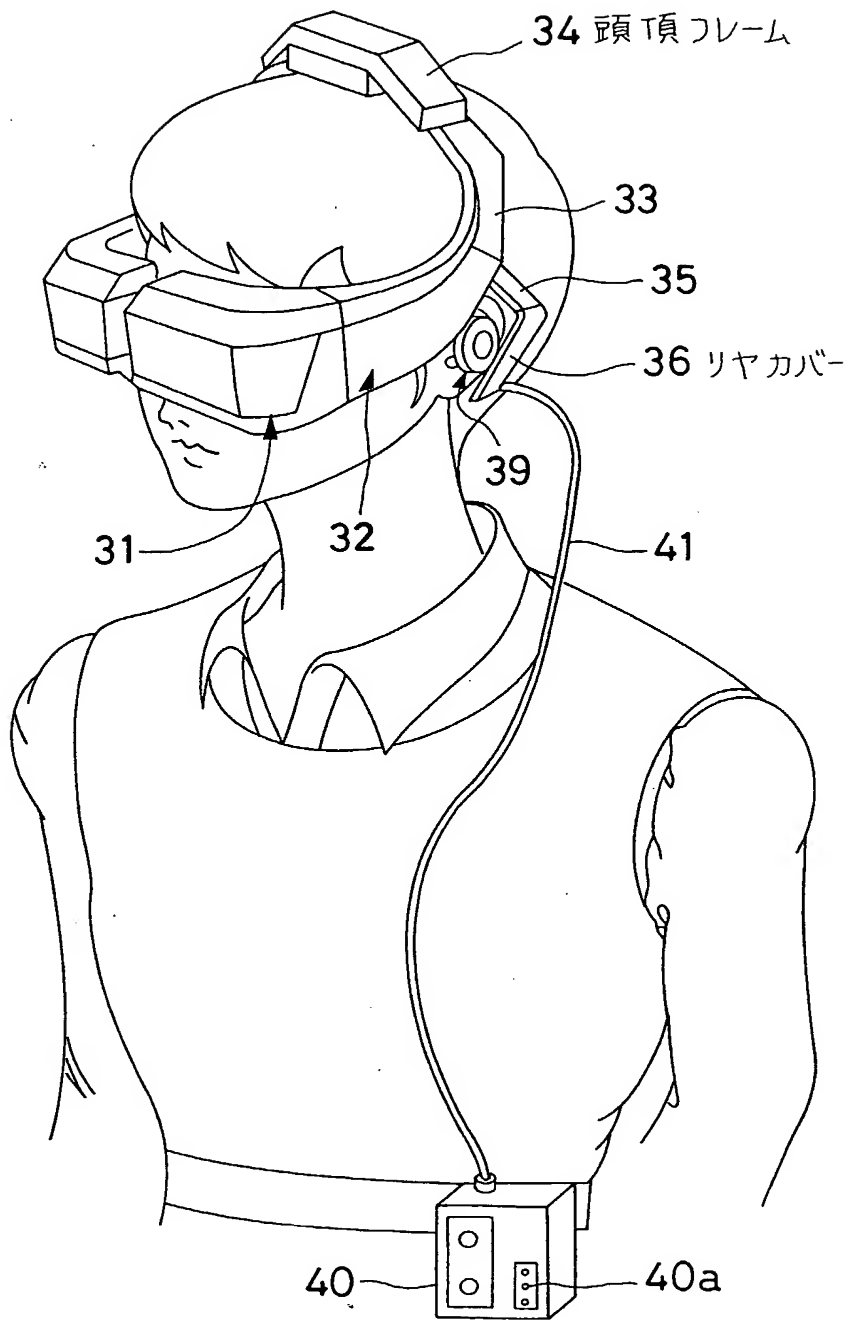
第３９図


2L
EL
4L
23L
16L
外界光
17L
22L(24L)
12R(13L)
11
21L
10
3
21R
22R(24R)
12L(13R)
17R
外界光
4R
ER
16R
23R
2R

第40図



第４１図



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP00/02549

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl^7 G02B 27/02 G09F9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int. Cl^7 G02B 27/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1991-1996 Toroku Jitsuyo Shinan Koho 1994-2000
Kokai Jitsuyo Shinan Koho 1991-2000 Jitsuyo Shinan Toroku Koho 1996-2000

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 10-282421, A (Olympus Optical Company Limited), 23 October, 1998 (23.10.98), Full text; Figs. 1 to 25 (Family: none)	1-53
A	JP, 9-61748, A (Olympus Optical Company Limited), 07 March, 1997 (07.03.97), Full text; Figs. 1 to 16 (Family: none)	1-53
A	JP, 7-287185, A (Sony Corporation), 31 October, 1995 (31.10.95), Full text; Figs. 1 to 11 (Family: none)	1-53
A	JP, 6-110013, A (Sega Enterprise Ltd.), 22 April, 1994 (22.04.94), Full text; Figs. 1 to 4 (Family: none)	1-53
A	JP, 5-176260, A (Sega Enterprise Ltd.), 13 July, 1993 (13.07.93), Full text; Figs. 1 to 3 (Family: none)	1-53

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
18 July, 2000 (18.07.00)

Date of mailing of the international search report
01 August, 2000 (01.08.00)

Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

国際調査報告	国際出願番号　ＰＣＴ／ＪＰ００／０２５４９

Ａ．　発明の属する分野の分類（国際特許分類（ＩＰＣ））
　Ｉｎｔ．Ｃｌ⁷　Ｇ０２Ｂ　２７／０２　Ｇ０９Ｆ９／００

Ｂ．　調査を行った分野

調査を行った最小限資料（国際特許分類（ＩＰＣ））
　Ｉｎｔ．Ｃｌ⁷　Ｇ０２Ｂ　２７／０２

最小限資料以外の資料で調査を行った分野に含まれるもの

日本国実用新案公報	１９９１－１９９６年
日本国公開実用新案公報	１９９１－２０００年
日本国登録実用新案公報	１９９４－２０００年
日本国実用新案登録公報	１９９６－２０００年

国際調査で使用した電子データベース（データベースの名称、調査に使用した用語）

Ｃ．　関連すると認められる文献

引用文献のカテゴリー＊	引用文献名　及び一部の箇所が関連するときは、その関連する箇所の表示	関連する請求の範囲の番号
Ａ	ＪＰ，１０－２８２４２１，Ａ（オリンパス光学工業株式会社） ２３．１０月．１９９８（２３．１０．９８） 全文、第１－２５図（ファミリーなし）	１－５３
Ａ	ＪＰ，９－６１７４８，Ａ（オリンパス光学工業株式会社） ７．３月．１９９７（０７．０３．９７） 全文、第１－１６図（ファミリーなし）	１－５３

☒ Ｃ欄の続きにも文献が列挙されている。　　☐ パテントファミリーに関する別紙を参照。

＊　引用文献のカテゴリー
「Ａ」特に関連のある文献ではなく、一般的技術水準を示すもの
「Ｅ」国際出願日前の出願または特許であるが、国際出願日以後に公表されたもの
「Ｌ」優先権主張に疑義を提起する文献又は他の文献の発行日若しくは他の特別な理由を確立するために引用する文献（理由を付す）
「Ｏ」口頭による開示、使用、展示等に言及する文献
「Ｐ」国際出願日前で、かつ優先権の主張の基礎となる出願の日の後に公表された文献
「Ｔ」国際出願日又は優先日後に公表された文献であって出願と矛盾するものではなく、発明の原理又は理論の理解のために引用するもの
「Ｘ」特に関連のある文献であって、当該文献のみで発明の新規性又は進歩性がないと考えられるもの
「Ｙ」特に関連のある文献であって、当該文献と他の１以上の文献との、当業者にとって自明である組合せによって進歩性がないと考えられるもの
「＆」同一パテントファミリー文献

国際調査を完了した日 １８．０７．００	国際調査報告の発送日 01.08.00
国際調査機関の名称及びあて先 日本国特許庁（ＩＳＡ／ＪＰ） 郵便番号１００－８９１５ 東京都千代田区霞が関三丁目４番３号	特許庁審査官（権限のある職員）　２Ｘ　９１２０ 瀬川　勝久　印 電話番号　０３－３５８１－１１０１　内線　３２９５

様式ＰＣＴ／ＩＳＡ／２１０（第２ページ）（１９９８年７月）

C（続き）．	関連すると認められる文献	
引用文献の カテゴリー＊	引用文献名　及び一部の箇所が関連するときは、その関連する箇所の表示	関連する 請求の範囲の番号
Ａ	ＪＰ，７－２８７１８５，Ａ（ソニー株式会社） ３１．１０月．１９９５（３１．１０．９５） 全文、第１－１１図（ファミリーなし）	１－５３
Ａ	ＪＰ，６－１１００１３，Ａ（株式会社セガエンタープライゼズ）２２．４月．１９９４（２２．０４．９４） 全文、第１－４図（ファミリーなし）	１－５３
Ａ	ＪＰ，５－１７６２６０，Ａ（株式会社セガエンタープライゼズ）１３．７月．１９９３（１３．０７．９３） 全文、第１－３図（ファミリーなし）	１－５３